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BODY TEMPERATURE AND RESPIRATION RATE, AND THEIR RELATION TO ADAPTABILITY IN SHEEP

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SHEEP producers in the "Deep South," or the Southwestern part of the United States have observed that certain breeds of sheep thrive better than others. The rather common practice of bringing into the South, breeds of sheep which thrive in the North or Middle West, has been disappointing in general. These failures have been attributed in the main to parasites, both external and internal. In many sections sheep are not grown today because of failures in the past.

In recent years greater effort has been made to find a breed or combination of breeds best adapted to certain areas in Mississippi, Louisiana, and parts of South and East Texas. While some progress has been made, no specific recommendations as to breed can be offered. Although spring breeding for fall-dropped lambs offers the greatest promise for successful lamb production, it has its limitations because too many ewes will not breed in the spring.

In summarizing the records of the Texas A. and M. College flock for several years it was noted that the mutton breeds (Hampshire and Southdown) had a very poor production record.[3] The Rambouillet flock had a somewhat better record and the Delaine Merino flock had the best record among the purebred flocks. A group of Southdown-Rambouillet crossbred ewes which had been in the flock for several years had the best record of all groups.

On the strength of the record made by the Southdown × Rambouillet ewes, other crosses have been introduced with equally good results. Since all groups are maintained under similar conditions, and since the use of phenothiazine has practically eliminated death losses from parasites, it was felt that differences in productivity must be associated with physiological differences in their ability to withstand prolonged high atmospheric temperatures.

The observations by Rhoad (1936) on cattle in Brazil and in Louisiana (Rhoad, 1938, 1940, 1940*a*) showed a marked difference in efficiency of heat disposal in favor of *Bos indicus* over *Bos taurus*. Hybrids between the two types were intermediate in their ability to control body temperature.

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Ability to control temperature results in greater productivity in hybrids than in *Bos taurus* (Aberdeen Angus) animals, as has been shown by Rhoad and Black (1943) and Rhoad, Phillips and Dawson (1945). Bonsma (1940) made similar observations in South Africa and stated that the Afrikander cattle are better adapted to withstand high temperature than exotic breeds because of their more efficient heat regulation. Among other factors responsible for the degenerate changes observed in purebred and high-grade cattle in a tropical environment, Daubney (1942) lists the effect of climatic conditions on the animals' heat-regulating system. Blum (1945) points out that in humans the maximum solar heat load may be two or three times the resting metabolic heat load, or about equal to the metabolic heat load of ordinary walking.

Anyone who has had opportunity to observe Brahman cattle or Brahman × European beef breeds in the Gulf Coast region of the United States will not question the superior heat-regulating mechanism of that type and its relationship to profitable beef production in that area.

Materials and Methods

Six breed groups of five ewes each were studied during July and August of 1943 and seven breed groups were studied in 1944. Purebred groups consisted of Rambouillet, Delaine Merino, Hampshire, and Southdown. Crossbred groups consisted of Suffolk × Rambouillet, Southdown × Rambouillet and Dorset × Rambouillet.

The ewes were selected for uniformity of age, type, and condition and the groups were made as similar as possible. The 35 experimental ewes were kept together during the period of the observations. Rectal temperature and respiration rate were determined on each individual ewe, taking one ewe from each group in rotation, and repeating in the same order until all ewes were observed. Respiration counts were made from the flank movement of the animals. Observations were repeated at different hours of the day from early morning until late afternoon. Care was taken to handle the ewes quietly and to avoid exertion or excitement. The hour and barn temperature for each individual observation was recorded.

Results and Discussion

In 1943 only one observation was made per day, but the hour of making them varied from 7A.M. to 8 P.M. Table 1 shows the variations in body temperature and respiration rate as the atmospheric temperature varied on the days of observations. It will be noted that the purebred groups showed the greatest increase of body temperature and respiration rate, and with one exception (August 12) the Southdown and Hampshire groups had the

highest temperature and respiration rate. The Merino and the two crossbred groups were less affected by high atmospheric temperature. The Suffolk × Rambouillet group was least affected by the high temperature.

TABLE 1. EFFECT OF ATMOSPHERIC TEMPERATURE ON BODY TEMPERATURE AND RESPIRATION RATE OF SHEEP SUMMER 1943

Body Temperature

Conditions and breed groups	Date and hour									
	7-10 10–12 A.M.	7-14 2–4 P.M.	7-21 4–6 P.M.	7-28 6–8 P.M.	8-6 8–10 A.M.	8-12 4–6 P.M.	8-18 7–9 A.M.	8-25 1–3 P.M.	9-6 10–12 A.M.	9-13 7–9 A.M.
Barn temperature, °F.	85.0	91.8	95.7	78.0	84.0	92.0	82.0	95.0	87.0	80.0
Humidity	75.8	81.0	76.0	100.0	82.5	79.0	92.0	70.0	78.5	81.5
Southdown	103.1	103.4	104.6	103.4	103.8	104.3	103.9	104.9	103.9	103.5
Hampshire	103.0	103.1	104.3	103.0	103.2	104.3	103.5	103.9	103.4	103.3
Merino	102.6	102.8	102.9	102.3	102.6	103.7	102.9	103.3	102.8	102.6
Rambouillet	102.2	102.4	104.3	102.6	103.6	104.8	103.4	103.7	103.3	102.9
Southdown×Ramb.	101.9	102.7	103.6	101.8	102.9	103.2	103.2	103.2	102.8	102.1
Suffolk×Rambouillet	102.3	102.9	103.4	102.0	102.8	103.5	102.8	103.1	102.6	102.3

Respiration Rate

Southdown	77	104	144	113	105	148	135	150	133	109
Hampshire	102	113	128	122	115	141	133	134	126	116
Merino	49	83	120	80	77	112	95	104	99	88
Rambouillet	53	74	127	94	89	144	120	135	114	97
Southdown×Ramb.	38	62	115	63	64	112	90	105	102	84
Suffolk×Rambouillet	33	58	84	40	49	96	49	78	66	41

In 1944 three to four observations were made daily on seven breed groups during each of five hot days in July and August. The increase in body temperature and respiration rate concurrently with the increase in atmospheric temperature from 8 A.M. to 5 P.M. is shown in figure 1. Except for the first day when the ewes were not given opportunity to cool after being driven into the observation pen from a nearby lot, there was generally a uniform increase in body temperature and respiration rate from 8 A.M. to 5 P.M. As in 1943 the Southdown and Hampshire ewes showed shomewhat higher temperatures. Although Rambouillets had a low temperature early in the day, the increase during the day was great. Dorset × Rambouillet ewes had a high early morning temperature but did not increase much during the day. Merino and Suffolk × Rambouillet ewes remained coolest during the entire day. Hampshire ewes had the highest respiration rate followed by Southdowns. Southdown × Rambouillet ewes had a high respiration rate during the latter part of the day but seemed to cool off well at night. Merinos were

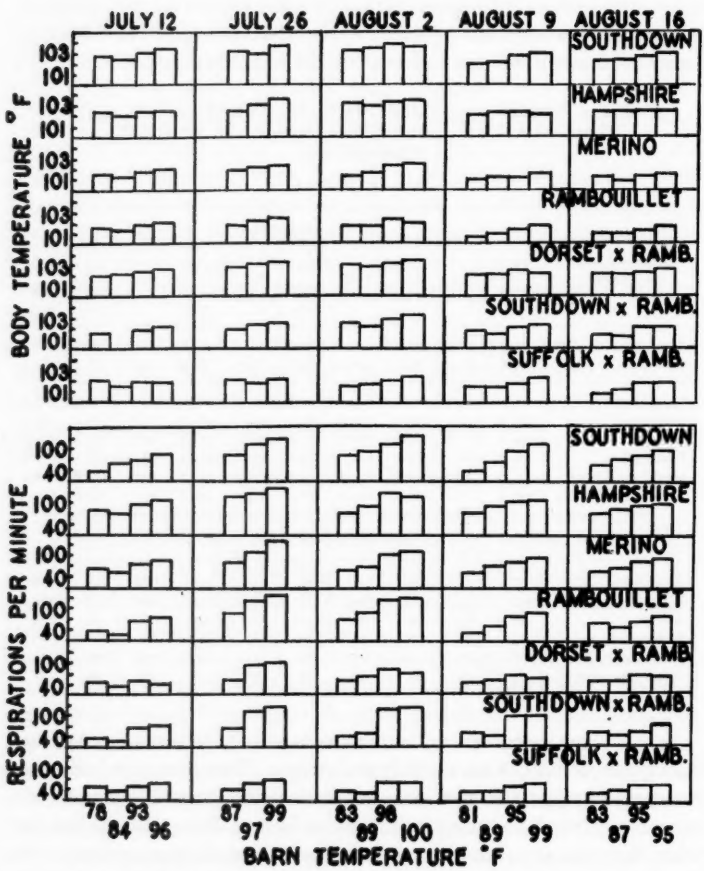

Figure 1. Effect of atmospheric temperature on body temperature and respiration rate of sheep, summer 1944.

somewhat less affected than Rambouillets. The crossbred groups as a whole were affected less than the purebred groups. Suffolk × Rambouillet ewes showed very slight effects of the high temperature.

Figure 2 shows the average of the five observations made on respiration rate and body temperature shown in figure 1. Daily fluctuations of respiration rate and body temperature for the seven groups of ewes over the five observation days are shown.

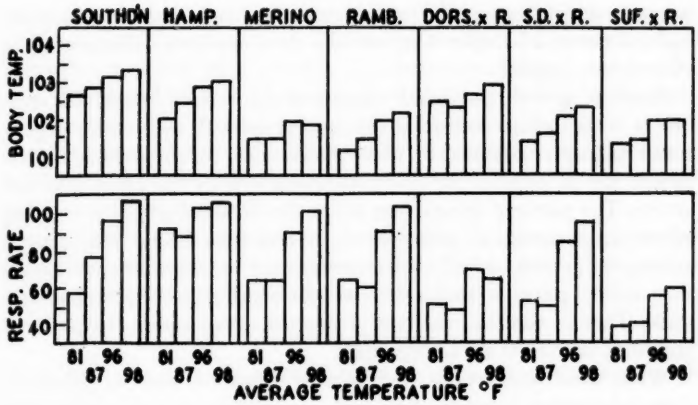

Figure 2. Average daily fluctuation of body temperature and respiration rate. (Average of five days, 8 a.m. to 5 p.m., summer 1944.)

Purebred Southdowns had the highest body temperature throughout the day. Except for the 8–10 A.M. period, when Dorset × Rambouillets were higher, Hampshires were next to Southdowns, and closely followed by Dorset × Rambouillets. Purebred Rambouillets had the lowest body temperature of all groups between 8 and 10 A.M., but their temperature increased almost one degree by the 3 to 5 P.M. period. Purebred Merinos and the Suffolk × Rambouillet groups maintained the most nearly constant and lowest average body temperature throughout the entire day.

Breed differences in respiration rate are more striking and fluctuate greatly with changes in atmospheric temperature. The purebred groups showed a higher respiration rate at each hour of the day than the crossbred groups. Suffolk × Rambouillet ewes had the lowest respiration rate of all groups throughout the day.

Only one comparison of crossbreds with both purebred parent groups is offered, i.e., the Southdown and Rambouillet. It is of interest to note that the Southdown × Rambouillet group was intermediate between the parent groups in each instance for body temperature, but their respiration rate was lower than either parent group for each period of the day.

These observations bear out the common opinion that the thicker fleshed, better mutton type sheep suffers more from high atmospheric temperature than the more angular and thinner fleshed wool type. However, it did not follow that the most extreme wool type was least affected by high temperature. It is difficult to explain why the Suffolk × Rambouillet ewes were

least affected (of all groups). They are somewhat rangy, with clean faces and legs and fleeces a bit open. Undoubtedly these are factors contributing to efficient heat disposal.

Breeding, growth and health records of the various breeds and cross breeds in the College flock are in close agreement with their thermo-regulatory efficiency as measured by these observations. Suffolk × Rambouillets ranked first in productivity and health, followed by the other crossbred groups. The purebred groups were below the crossbred groups in breeding efficiency, percentage of lambs raised, freedom from disease and parasites and rate of growth of lambs. Merinos appeared to be best adapted among the purebred groups to the conditions under which these observations were made. They in turn had the best production record among the purebred groups maintained in the College flock.

While these observations were somewhat limited, they do indicate a close relationship between type and adaptability to high atmospheric temperatures, a factor which should be considered in the selection of breeding stock for the South and Southwest.

Summary

1. Body temperature and respiration rate determinations were made on six uniform breed groups of five ewes each in the summer of 1943 and on seven groups in 1944. Purebred groups consisted of Southdown, Hampshire, Merino and Rambouillet. Crossbred groups consisted of Southdown × Rambouillet, Dorset × Rambouillet and Suffolk × Rambouillet.

2. Determinations were made at different hours of the day from 8 A.M. to 5 P.M. on each ewe, and average values for each breed group were used for comparisons. Atmospheric temperature and relative humidity recordings were made.

3. With few exceptions Southdown and Hampshire groups in that order showed the highest body temperature and respiration rate at all hours of the day.

4. Rambouillet and Merino groups were quite comparable on body temperature and respiration rate, and somewhat lower than the Southdown and Hampshire groups.

5. The crossbred groups had lower respiration rate than the purebred groups but their body temperature was quite comparable to that of the fine wool breeds (Merino and Rambouillet).

6. Body temperature and respiration rate in purebred groups were influenced more by atmospheric temperature changes than in the crossbred groups.

7. Suffolk × Rambouillet ewes maintained the lowest respiration rate of

all groups at all times and were least affected by atmospheric temperature changes. They also maintained a relatively low body temperature which fluctuated very little with atmospheric temperature changes.

8. Merinos showed the lowest body temperature and respiration rate, and the least daily fluctuation among purebred groups.

9. Breeding, growth and health records of the various breed groups in the College flock are in close agreement with their efficiency of heat disposal as measured by these observations.

10. Further investigations on a more extensive scale are necessary before generalizations can be made, but the correlation between thermo-regulatory efficiency and flock record is more than a coincidence.

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INHERITANCE OF SKIN FOLDS OF SHEEP

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ONE of the distinguishing characteristics of the finewool breeds of sheep is the presence of skin folds or wrinkles. These range in size and number from a very slight looseness on the lower line of the neck to skin folds so large and so numerous as to almost completely cover the body. The inherent tendency to have skin folds was evidently present in the early Spanish Merinos from which all the fine wool breeds have descended (Randall, 1863). It was found early by practical breeders that these skin folds could be increased rather easily by selection.

There have been differences in view point in regard to the desirability of skin folds (Austin, 1943). Some of the early breeders of Merinos in America held to the view that the more wrinkles, the greater the skin area and so as a matter of course there would be more wool-producing area, resulting in a heavier fleece. Others maintained that the skin folds were directly associated with density, resulting in more wool on the same area, as well as more area to grow wool. These views led to the production, especially in Vermont and some of the other eastern states, of sheep with the apparent maximum number of skin folds that could be present on an animal. On the other hand, breeders of the strictly Delaine Merino type tended to select for smoothness, limiting the wrinkles to the neck folds, with a considerable degree of success. Breeders of Rambouillets have tended to favor an intermediate type. However, to maintain this intermediate type recourse has been made both to rather wrinkly and smooth types of rams. Practical observations led many breeders to believe that breeding for smoothness leads to a marked reduction in wool production. All or practically all of the above is based on unscoured wool production. The relationship to clean wool production will be discussed later.

The more wrinkly types of finewool sheep have had heavier shrinking fleeces probably due in most instances to the abundance of oil or wool fat

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secreted by the sebaceous glands. This excessive oil or grease, together with the wrinkles, has led to more difficulty in management of the sheep in areas where screw worm flies and wool worm flies are prevalent. Also, buyers of feeder lambs have tended to discriminate against wrinkly lambs, whether justly or not. One of the reasons given for discriminating against the wrinkly lambs was that the pelts were less valuable for leather than were those from smooth lambs (Arnold, 1925). Furthermore the dressed yield of the wrinkly type lambs is lowered due to their heavier pelt.

Many ranchmen, especially in Texas, have concluded that it is more profitable to breed the smoother type even though the grease wool production is in many instances markedly lower than with the more wrinkled type. Studies by Jones et al. (1944) have shown that in the Texas Station's flock of Rambouillets the B type (wrinkly) ewes produced approximately one pound more unscoured wool than was produced by the smooth or C type ewes. However, this difference was caused by the heavier shrinkage of the fleeces produced by the wrinkly or B type ewes together with the scarcity of long stapled fleeces among the B type ewes. There was no significant difference in clean wool produced by the B type and C type ewes. There was a small but significant difference in staple length in favor of the smooth or C type. Also the C type wool was more uniform in both length of staple and in diameter of fiber. Further study of these data showed that clean wool from fleeces of the same staple length classification was greater for the B type. However, only 9 percent of the B type fleeces were 2.5 inches or more compared to 37 percent in the C types. Presumably the extra clean wool of the B type fleeces of the same length as the C type is caused by the greater skin area. If wool is sold on the basis of its shrinkage or net yield as well as grade, there is no advantage in favor of the wrinkly type, the differences being in favor of the smooth or C type sheep. However, until the economics of wool marketing has been developed to the point where the individual producer is paid directly on the basis of clean wool, considerable attention should continue to be given by the producer to unscoured fleece weights even though it may be necessary to tolerate some skin folds to maintain unscoured fleece weights.

While it is true that breeders had early found by practical experience that skin folds could be increased or decreased rather easily by selection, little was known about the actual inheritance of this character. Many isolated experiences needed a logical explanation. Frequently rather smooth rams (C type) would sire what seemed to be too many wrinkly lambs. Sometimes the opposite ensued, i.e., a wrinkly ram (B type) might sire more smooth lambs than it seemed logical to expect.

Realizing the scarcity of definite information on the entire subject relat-

ing to comparative weights, lengths and fineness of wool produced by relatively smooth bodies Rambouillet sheep as compared with those carrying various degrees of skin folds, a study was initiated in 1918. The comparative production of B and C types has been reported by Jones et al. (1944). A further objective was the possibility of the development of a relatively smooth bodied Rambouillet possessing the desired fleece characteristics which could be maintained without having to resort to the use of sires or dams of heavy skin-fold development for the purpose of maintaining unscoured fleece weight.

For the purpose of studying the inheritance of skin folds it was necessary first to record in detail the number, size and location of the skin folds on a fairly large number of finewool sheep. This was to learn whether a record of the entire skin surface would be necessary, if the different body regions were definitely associated with each other and with the whole skin surface, and whether the character was expressed differently in the two sexes. After this was done, a study of parent offspring relationship was made for the purpose of determining how much of the variability observed in this particular group of animals was due to heredity and how much to other causes. In addition, it was the hope that some light would be thrown on the mode of inheritance. Finally, a few crosses were made between Corriedale ewes (smooth) and Rambouillet rams for further study of the inheritance of skin folds.

Materials and Methods

Numerical values based on the number and size of skin folds were given to each sheep studied. These records were taken soon after shearing so as to avoid the obscuring influence of the fleece. Record sheets were used showing both front and side view outline sketches of a sheep, and a printed tabular outline on which to record the number and the relative size of the skin folds by regions (figure 1). The approximate location and relative size differences were shown by drawings on the sketches, and immediately following this the numbers were recorded in tabular form. For this purpose seven regions of the body were designated as follows: face, top neck, under neck, shoulder, side, tail head, and thigh. The relative skin fold sizes were designated as trace, small, medium, and large. Arbitrary values assigned to these sizes were 1, 2, 4, and 8, respectively, these being the apparent approximate differences. The values recorded were totaled first by body regions and then combined to give a total skin-fold value for the animal. An example of the method of recording, based on the animal sketched in figure 1, is shown in the table on the next page.

Since the data of this study were collected and much of the analysis completed, photographic standards for classifying skin folds have been pub-

Location	Number of folds				Skin-fold value
	Trace	Small	Medium	Large	
Face	0	0	0	0	0
Neck (top)	5	0	1	0	9
Neck (under)	0	0	1	2	20
Shoulders	1	0	0	0	1
Side	0	0	0	0	0
Tail head	0	1	0	0	2
Thigh	0	0	0	0	0
Total skin-fold value					32

lished by Madsen, Esplin and Phillips (1943); and Carter (1943) included a detailed set of drawings and photographs, to illustrate the different types and amounts of skin folds, in the report of his study of the biology of the skin and fleece of the sheep.

Purebred Rambouillets were used for much of the study. The records of the Rambouillets analyzed in this study were all from animals of approximately one year of age, i.e. just after the first-year fleece was shorn. Results secured from these data should be similar to those from data collected at other ages as it has been shown by Madsen, Esplin and Phillips (1943) that the correlations between skin fold scores at different ages are highly significant. In addition to the Rambouillets, crossbred animals, resulting from the mating of purebred Corriedale ewes to Rambouillet rams, F_2 and backcross progenies were included. The records from part of these crossbreds

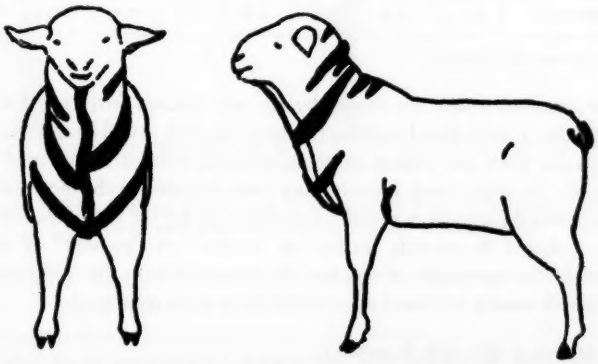

Figure 1. Example of the method of sketching skin folds on the record form for each animal. Numbers and relative sizes of folds on each body area were also recorded, as is shown in the text.

were taken when the animals were between 5 and 7 months of age, as they were shorn in the fall. Rambouillets studied include 760 males and 915 females. Crossbreds represent 67 males and 72 females. The sheep studied were in the flock at Substation Number 14, Sonora, Texas. Data from the Rambouillets, collected during the years 1923 to 1941 inclusive, were used. Standard statistical methods were used in the analysis of the data.

Results

Comparison of skin-fold values by body regions and sex

In Rambouillets the average skin-fold value for each body region is given by sexes in table 1. This shows that the neck regions have higher values than any of the others. Combined values for top and under neck represent over half of the total. The differences between regions are highly significant in every case. The males averaged significantly higher than the females for each region and for the total. The total skin-fold values for the males are approximately 25 percent higher than those of the females. These differences suggest that skin folds are affected by sex or that they represent a sex-influenced character.

TABLE 1. COMPARISON OF SKIN-FOLD VALUES BY SEX AND BODY REGIONS ON RAMBOUILLET SHEEP

Sex	Face	Top neck	Under neck	Shoulder	Side	Tail head	Thigh	Total
Male	2.8	13.4	16.8	3.8	6.3	4.1	9.0	56.1
Female	1.3	9.9	13.5	3.0	4.6	3.2	6.7	42.3
Difference[1]	1.5	3.5	3.3	0.8	1.7	0.9	2.3	13.8

[1] Each difference highly significant.

The skin-fold values are classed by size and percent frequency for each sex. In table 7 under Rambouillet, and also in figure 2, it will be seen that the two classes with the lowest values have more females represented than males. On the other hand, some females were included in the more wrinkly classes, even though the maximum is represented by the male. We feel that while it would be entirely feasible to "correct" or "convert" all of the records to the equivalent of one sex, the records within the respective sex groups will usually be found more useful than when combined.

Correlations of skin folds by regions

In order to determine whether the skin folds of the different body regions are due to common causes, correlations between parts were computed for

all possible combinations and each part with the total, and also with the remainder. These coefficients, as shown in table 2, are all highly significant. As the expression of skin folds in the different regions is not independent, the skin folds of all regions must be due to general skin fold genes rather than being regionally specific. Skin-fold total may be safely used in comparisons of different groups of animals as each region is highly and significantly correlated with total.

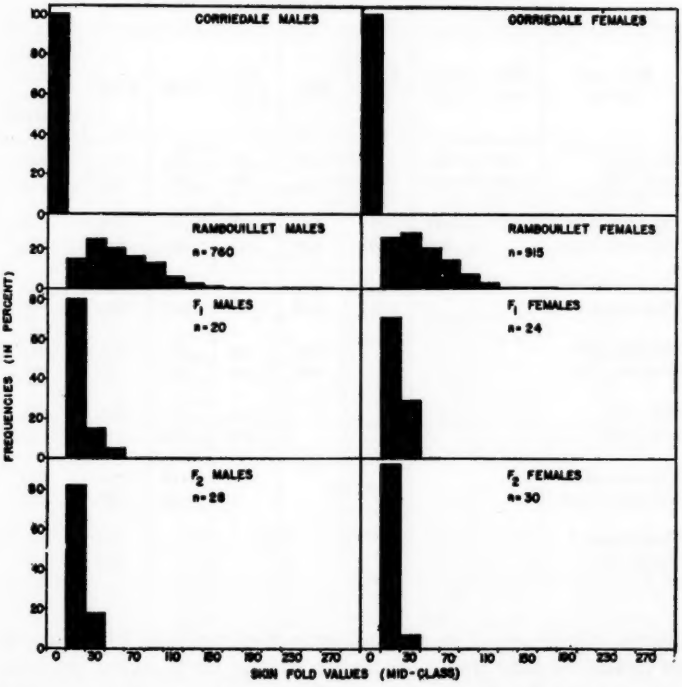

Figure 2. Distributions of total skin-fold values of Corriedales Rambouillets and of crosses between Corriedales and Rambouillets.

It is often assumed that the part to total coefficients are spurious and cannot be tested against an assumed zero. However, it has been shown by Baker (1942) that such correlations are valid and may be useful. The relationship of total to separate part is of more direct interest in this study than that of part to the remainder. This is because the only real purpose of the correlation of part to the remainder is for use in estimating the total skin fold

value of the animal from the record of one part only. Accordingly, if the estimate of the animal is made by using the regression coefficient for part to remainder the coefficient is found to differ from that of part to total by 1, (see table 3). The standard error of estimate for total and the corresponding standard error of estimate for the remainder are identical. It will be seen

TABLE 2. CORRELATION COEFFICIENTS OF SKIN FOLD VALUES BETWEEN REGIONS, BETWEEN REGION AND TOTAL, AND BETWEEN REGION AND TOTAL MINUS THE REGION CORRELATED

Body area and sex	Top neck	Under neck	Shoulder	Side	Tail head	Thigh	Total	Total minus region correlated
Face, rams	.356	.402	.388	.266	.286	.384	.512	.440
Face, ewes	.226	.290	.307	.244	.267	.312	.404	.334
Top neck, rams		.555	.681	.640	.578	.539	.858	.740
Top neck, ewes		.639	.602	.545	.502	.492	.816	.684
Under neck, rams			.468	.407	.523	.576	.770	.630
Under neck, ewes			.622	.508	.533	.642	.864	.737
Shoulder, rams				.705	.544	.573	.801	.753
Shoulder, ewes				.677	.497	.592	.799	.753
Side, rams					.500	.555	.790	.675
Side, ewes					.460	.614	.772	.668
Tail head, rams						.548	.712	.664
Tail head, ewes						.592	.687	.634
Thigh, rams							.796	.691
Thigh, ewes							.809	.718

that the relative sizes of the standard errors of estimate from lowest to highest parallel the order of sizes of r for part to total, but in reverse order, i.e., the correlations from highest to lowest. The standard errors of estimate with their corresponding correlation coefficients for part to total minus part do not follow the same relative order as the corresponding correlation coefficients for part and total. So far as their use in estimating total skin-fold values is concerned the results will be identical. The only difference is that one additional step is involved where the total minus part is obtained first, as it is still necessary to add the value of the part to get the final estimated total value. Accordingly, in these data the coefficients of correlation of part to the remainder are largely of academic interest.

It will be seen from table 3 that the different parts do not stand in the same order for males and females. However, the correlations of all parts with total are quite high except those for face and tail head. This is reflected in relatively low errors of estimate, which indicates that we might have a wide choice of regions of the body to use for estimating the total skin-fold value. It seems logical to assume that neck, both top and under, either separately or together might be used to advantage. Using the data from males, a correlation of plus .928 was found between the neck regions (top of neck plus under neck) and total skin folds. The corresponding r for data from females was plus .929. These two regions, top of neck and under neck, are the most prominent skin-fold regions of the body and represent increasing proportions of the total skin-fold value as the average skin-fold value of a flock decreases. These considerations indicate that the skin-fold values of the

TABLE 3. ANALYSIS OF VARIANCE BY REGRESSION, OF SKIN-FOLD VALUES OF SHEEP

Parts correlated		Total skin-fold values = x	Total skin fold values minus part correlated = x − part	Standard error of estimate[1]	Regression equation for estimating total skin folds minus part	Regression equation for estimating total skin folds
Males						
		r	r			
Top neck	(B)	.8575	.7400	18.09	1.94B + 16.86	2.94B + 16.86
Shoulder	(D)	.8001	.7530	21.09	6.05D + 29.07	7.05D + 29.07
Thigh	(G)	.7959	.6914	21.25	2.68G + 23.09	3.68G + 23.09
Side	(E)	.7897	.6752	21.57	2.46E + 34.31	3.46E + 34.31
Under neck	(C)	.7705	.6304	22.41	2.05C + 4.94	3.05C + 4.94
Tail head	(F)	.7129	.6639	24.65	6.89F + 24.15	7.89F + 24.15
Face	(A)	.5135	.4403	30.17	4.54A + 40.71	5.54A + 40.71
Females						
Under neck	(C)	.8645	.7370	14.40	1.73C + 5.31	2.73C + 5.31
Top neck	(B)	.8159	.6844	16.57	1.99B + 12.69	2.99B + 12.69
Thigh	(G)	.8088	.7178	16.85	2.99G + 15.59	3.99G + 15.59
Shoulder	(D)	.7986	.7530	17.24	6.27D + 20.12	7.27D + 20.12
Side	(E)	.7725	.6679	18.20	2.81E + 24.71	3.81E + 24.71
Tail head	(F)	.6874	.6336	20.81	6.42F + 18.63	7.42F + 18.63
Face	(A)	.4035	.3345	26.22	4.13A + 35.56	5.13A + 35.56

[1] Standard error of estimate is for either total skin folds or total minus the part correlated.

neck regions give sufficient information to serve as a guide in selection and may replace total skin-fold value in practical work. Of course, no partial record can be as good as a complete record. However, taking and recording of detailed records on large numbers of animals may easily become so time-consuming as to be impractical for general use.

Variance and covariance of parent offspring groups

To estimate the genetic variation in total skin folds an analysis of variance and covariance was made for male and female progeny groups from 29 sires.

TABLE 4. ANALYSIS OF VARIANCE AND COVARIANCE FOR SKIN FOLD VALUES OF DAM AND DAUGHTERS

Source of variance	Degrees of freedom	Mean squares			Errors of estimate	
		x(=Dams)	y(=daughters)	xy	Degrees of freedom	Mean squares
Intra-year	523	630.6	613.3	133.9	522	
Between sires	53	995.6**	935.6**	132.2	53	925.610**
Within sires	470	589.4	590.4	134.1	469	61.037

** Statistically significant. P<.01.

TABLE 5. ANALYSIS OF VARIANCE AND COVARIANCE FOR SKIN FOLD VALUES OF DAMS AND SONS

Source of variance	Degrees of freedom	Mean squares			Errors of estimate	
		x(=dam)	y(=sons)	xy	Degrees of freedom	Mean squares
Intra-year	430	736.9	696.1	195.6	429	
Between sires	53	1079.3**	1079.0**	−8.6	53	1196.058**
Within sires	377	664.8	642.3	224.3	376	568.127

** Statistically significant. P<.01.

Only sires which produced 5 or more sons and 5 or more daughters were used in this analysis. The results of this analysis are summarized in tables 4 and 5. Inspection of these tables shows that the amount of variation between sires was statistically significant in both the male and female progeny groups. This difference between sires indicates the superiority of some sires over others in producing progeny with greater or lesser skin-fold values and therefore indicates that selection for or against this character should be successful. It may also be observed from these tables that there is a signifi-

cant difference in the skin-fold values of the group of dams according to the sires to which they were mated. After adjusting by covariance for the influence of dams there is still a significant difference between the progeny of different sires. The significant influence of season has been held in statistical control in this analysis. The genetic composition of the flock varied somewhat from season to season, because of changes in sires and dams. In addition to this the nutritional level varied with season. Carter (1941) has reported the direct influence of nutrition on number and size of skin folds, animals on the higher plane of nutrition having the greater values. This is supported by the findings of Hazel and Terrill (1944), who found that single lambs and offspring from older ewes had better scores on condition and also more neck folds. Glembockii and Nahimson (1940) observed that the greater the body weight of lambs the more skin folds they possessed. These data were also analyzed without removing the variation due to season with very similar results.

Correlations of dam to daughter, dam to son, half brothers to half brothers, and half sisters to half sisters are shown in table 6. Any one of these correlations may be used in estimating the proportion of the variability in these data that is due to heredity. The four correlations for dam to off-

TABLE 6. CORRELATION COEFFICIENTS FOR TOTAL SKIN FOLDS OF RELATIVES

Relative correlated	Variation due to season removed	Variation due to season not removed
Dam to daughter	.2275	.2172
Dam to son	.3432	.2412
½ brother to ½ brother	.0980	.1373
½ sister to ½ sister	.0712	.2085

spring do not differ significantly from each other and so are estimates of the same parameter. The half-sib correlations are not homogeneous as shown by the intra-year correlation of half-sisters being significantly lower than that found from the data where the year to year variation was not statistically controlled. There were no statistically significant differences between any of the correlations when the seasonal variation was not removed. These correlations were averaged, each component being weighted according to the reciprocal of its respective variance, and from this the heritable portion of the variation was found to be 45.6 percent. Using the correlations where the variation due to season was removed there is a significant difference between the correlation for dam to son and half sister to half sister. However, the average of the four correlations was used to estimate the heritable

portion of the variation and was found to be 51.2 percent. Definite progress can be made in selecting either for or against a character with estimates of the heritability of these magnitudes. This progress may be expected without special study of relatives and without progeny testing the sires.

Inheritance of Skin folds

The wild species of true sheep are all free from skin folds. Evidence from several sources (Ewart, 1913; Benchley, 1937; Warwick and Berry, 1941) points strongly toward the wild mouflon type as the principal progenitor

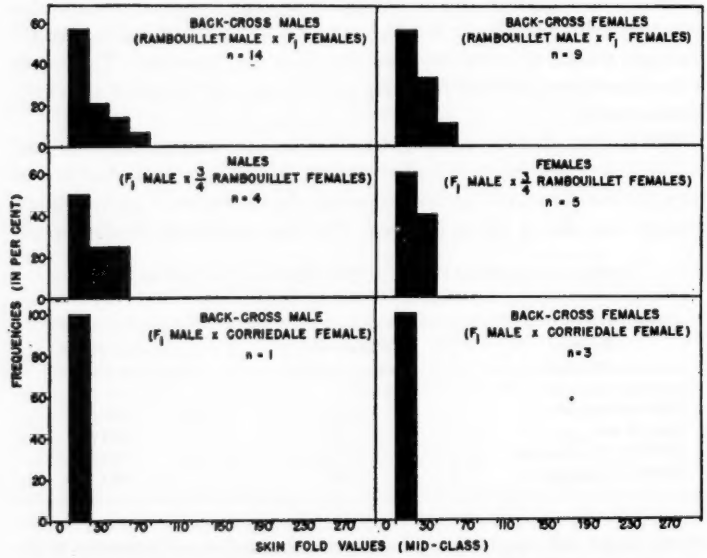

Figure 3. Distributions of total skin-fold values of backcross populations (F_1 to both parent breeds), and of $F_1 \times \frac{3}{4}$ Rambouillet animals.

of Merinos and Rambouillets. The skin folds typical of the finewool breeds must be the result of the occurrence of and preservation of mutations since domestication. A few crosses of a Mouflon (*Ovis musimon*) male with grade Rambouillet females made at the Texas Station resulted in F_1 progeny completely devoid of skin folds. Many crosses of finewool ewes with males lacking skin folds have been made in this country for commercial purposes. The great majority of the F_1 lambs were practically smooth, while a few

had a small number of skin folds, and very rarely a wrinkly lamb would result. One of the smooth breeds, the Corriedale, was produced by selecting F_1, F_2 and succeeding progeny from a large number of long-wool × fine-wool (smooth × wrinkly) sheep. The resulting Corriedale breed is almost free from wrinkles.

A few crosses of Corriedale ewes with Rambouillet rams, and some back-crosses to both parent breeds, are included in this study. They are shown in table 7 and figures 2 and 3. The F_1 progeny all had some skin folds but the values were low. Two of the smoothest F_1 rams were used to sire the F_2 progeny and the values obtained from these F_2 were even slightly lower than those of the F_1 population. F_1 ewes bred to two different Rambouillet rams produced progeny with greater skin-fold values than F_1 or F_2, but not as great as those of the parental group of Rambouillets. Four progeny sired by one of the low value F_1 males and out of Corriedale ewes were almost completely smooth.

None of the above progenies should be considered true F_1 or F_2 because of the hybrid origin of the Corriedale and the high variability of the Rambouillet. However, the results are suggestive of dominance of multiple genes. This is based on the following: (a) crosses involving smooth × finewool breeds give F_1 progeny either smooth or predominantly approaching the phenotype free from skin folds; (b) with small numbers F_2 progeny are similar to F_1; (c) back crosses to the wrinkly parental breed increased the variability in the direction of the wrinkly parent; (d) the frequency distribution of the Rambouillet flock for the period of years studied is suggestive of a modified F_2 population. The bulking of numbers at the smooth end of the Rambouillet distribution and the tailing out at the other end with a few relatively high values point in this direction. On the other hand, if this were a true F_2 population we would expect some completely smooth individuals. It has long been known that when breeding from an F_2 population the succeeding populations will continue to give distributions approximately like F_2 so long as the matings are random. When matings are not random, and there is a tendency to mate unlikes together, it tends to reduce the extremes. In this population there is a small negative correlation between the total skin-fold values of the sires and of the dams, indicating that there was a tendency to mate unlikes. No matings between extremely smooth individual Rambouillets were made during the course of this investigation. (e) It seems highly improbable that the highest skin-fold value represented in this study is as high as theoretically possible. This would make it necessary to postulate a type of inheritance in which the recessive end of the curve would have very low probability, so that even in large populations these ex-

TABLE 7. DISTRIBUTIONS OF VALUES OF SKIN FOLDS OF RAMBOUILLETS AND CROSSES WITH CORRIEDALES

Mid-class value	Rambouillet				F_1				F_2				Rambouillet×F_1				F_1×¾ Rambouillet				F_1×Corriedale			
	Males		Females		Males		Females		Males		Females		Males		Females		Males		Females		Males		Females	
	N[1]	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
10	116	15.26	242	26.45	16	80.00	17	70.89	23	82.14	28	93.33	8	57.14	5	55.56	2	50.00	3	60.00	1	100.00	3	100.00
30	191	25.13	256	27.98	3	15.00	7	29.19	5	17.86	2	6.67	3	21.43	3	33.33	1	25.00	2	40.00				
50	151	19.87	184	20.11	1	5.00							2	14.29	1	11.11	1	25.00						
70	121	15.92	129	14.10									1	7.14										
90	97	12.77	68	7.43																				
110	48	6.31	30	3.27																				
130	23	3.03	2	.22																				
150	9	1.18	3	.33																				
170	2	.26	1	.11																				
190	0	0	0	0																				
210	0	0	0	0																				
230	1	.13	0	0																				
250	1	.13	0	0																				
Totals	760		915		20		24		28		30		14		9		4		5		1		3	

[1] N=number.

treme classes would be absent. (f) It may easily be possible that the phenotype for smooth may include more than one theoretical smooth group. If so, it would be possible to reconcile the very rare occurrence of a fairly wrinkly lamb from matings involving a breed in which wrinkles are absent. The theoretical distributions in F_2 with several pairs of dominant genes are shown in figure 4. Also for comparison a typical distribution without dominance is shown. Several alternate theories may be used to explain the above facts. One of the more attractive of these is the postulating of one major pair of dominant genes with several pairs of minor genes. If it is necessary to assume that there are several pairs of genes, it would seem logical to use the simpler approach, unless definite evidence becomes available to make this untenable. However, the number of genes is probably not extreme.

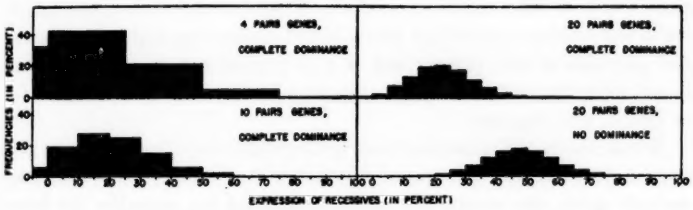

Figure 4. Theoretical distributions in F_2 populations with varying numbers of pairs of genes.

It should be of interest to consider what may be expected in practical breeding on the basis of the above facts and tentative interpretation. Within the breed, selection for freedom from skin folds or for very low skin-fold values should bring about very rapidly both a low average skin-fold value and a reduction of extremely wrinkly segregates to the point where they practically disappear. Breeding finewool breeds to the smooth breeds results in the almost complete removal of wrinkles in the first generation. The wrinkly offspring may show up again in F_2, but if there is any appreciable selection toward the smooth type in succeeding generations the wrinkly offspring will be extremely rare. This will be true so long as the wrinkly parental type is not backcrossed into the crossbred stock. In other words, phenotypic selection either within the breed or among crossbreds should result in rapid progress in the removal of skin folds. If complete elimination, genotypically as well as phenotypically is desired, progeny testing would be useful in the later generations of selection. If this is not considered necessary selection alone may be ample.

Summary and Conclusions

Skin folds were recorded and evaluated on 760 rams and 915 ewes of the Rambouillet breed. The records were taken on freshly shorn yearlings The males had significantly greater skin-fold values than the females. The skin-fold values of all body regions were highly and significantly correlated with each other, with total skin folds and with total minus the part correlated.

Regression coefficients for estimating the total skin folds from the record of a part differed by one in each case from those using total minus the part. Either may be used, but that using total skin folds is simpler. The neck regions, top and bottom, may be used either separately or together with a fairly high degree of reliability to replace the record of the entire animal.

Analysis of variance and covariance of parent-offspring groups was made with the progeny of 29 sires. This showed a significant influence of sires. Correlations of other relatives, i.e. dam to daughter, dam to son, half brothers to half brothers, and of half sisters to half sisters were highly significant, and estimates of 45.6 percent and of 51.2 percent heritable portion were found, indicating that definite progress may be expected from selection for or against this character.

A few crosses of Rambouillet rams to Corriedale ewes (smooth) were also studied. It is tentatively proposed that lack of skin folds is due to dominant multiple genes, the number not being determined but probably not being extremely large.

It is concluded from both phases of the study that skin folds may be easily reduced to a low point by selection alone. Progeny tests would be necessary only if complete elimination is desired, or if the objective is an intermediate type.

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HERITABILITY OF FACE COVERING AND NECK FOLDS IN RANGE RAMBOUILLET LAMBS AS EVALUATED BY SCORING

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AN OPEN face is desirable for most efficient lamb production in range sheep and is not inconsistent with heavy wool production. Terrill (1941) found that Rambouillet ewes with open faces produced nearly 9 pounds more of lamb per year than those with covered faces and that the amount of clean wool produced was about equal for the two groups. These results were confirmed by Peters (1945). Wool blindness, resulting from a covered face, necessitates frequent clipping around the eyes so that the sheep can see to eat and drink. Most fine-wool range sheep have some wool covering on the face. Therefore, selective breeding for open faces is an important problem in the improvement of range sheep.

Selection for smoothness in preference to wrinkles or folds of the skin is now a common practice in Rambouillet flocks. Jones *et al.* (1944) found that smooth Rambouillets generally produce longer staple and more uniform fleeces than those with wrinkles. They also found that the weights of clean fleece from smooth-bodied ewes were equal to those from wrinkled ewes but that the weights of grease fleeces from the latter ewes were about 1 pound more. Smooth sheep are more easily sheared, are less subject to fly trouble and produce more valuable skins than wrinkled sheep. Purchasers of feeder lambs often discriminate against lambs with wrinkles or folds.

Open-faced, smooth sheep have definite economic advantages over sheep with covered faces and skin folds or wrinkles. Therefore, the rapid conversion of range fine-wool sheep to an open-faced smooth type is desirable and will simplify further efforts in breeding for improvement of other characteristics in range sheep. Reliable estimates of heritability of these traits are needed to formulate breeding plans so as to fix open face and smoothness in fine-wool range flocks rapidly and efficiently. The object of this study is to estimate the heritabilities of face covering and neck folds in weanling Rambouillet lambs.

Data and Methods

Data on face covering and neck folds were taken from 2183 weanling range Rambouillet lambs in 1941 and 1942 at the Western Sheep Breeding

[1] Western Sheep Breeding Labratory, Dubois, Idaho.

Laboratory, Dubois, Idaho. Similar data taken in previous years on 892 dams of these lambs were also included. Practically no selection had occurred prior to the taking of the weanling data.

The lambs were scored for face covering and neck folds soon after weaning by each of two or three experienced animal husbandmen. Wool covering on the face was scored as follows: "1" not covered beyond the poll, "2" covered to the eyes, "3" covered slightly below the eyes but open faced, "4" covered below the eyes but not entirely covered and subject to wool blindness, "5" almost or entirely covered and subject to wool blindness. Illustrations of faces of Rambouillet weanling range lambs showing various degrees of face covering are presented in figure 1.

The occurrence of skin folds or wrinkles on the neck was scored as follows: "1" no folds, "2" very few folds of small or moderate size, "3" folds of moderate number or size, "4" heavy or large folds of moderate or large number, and "5" completely covered with heavy or large folds. Illustrations of necks of weanling Rambouillet lambs showing various degrees of neck folds are presented in figure 2. Heavier degrees of neck folds were not available in this flock when the photographs were taken.

Fifteen scoring units were possible by assigning plus or minus values to lambs considered as being slightly above or below an even unit. Average scores of the committee were used in the analysis. These scores were adjusted for environmental factors (sex, age of dam, type of birth and rearing, age at weaning, and percent inbreeding) according to the differences found in these same data by Hazel and Terrill (1945a).

The method of analysis used in estimating heritability and in correcting for inbreeding was identical to that presented by Hazel and Terrill (1945b).

Results and Discussion

Presentation of Results

Distributions of face-covering and neck-folds scores are presented in figure 3 for both ram lambs and ewe lambs. The distributions are skewed for both traits. Neck-fold scores are skewed toward the smooth or lower end, and selection is being practiced in the same direction. Face-covering scores are skewed toward the covered or upper end while selection is directed toward more open faces. This indicates that variability of neck folds is probably declining while that of face covering will probably increase before the scores become concentrated around the desired face covering as represented by scores of 3 and 3+.

Mean squares for face-covering and neck-folds scores are presented in table 1. Lambs from the same sire tended to be similar both in respect to

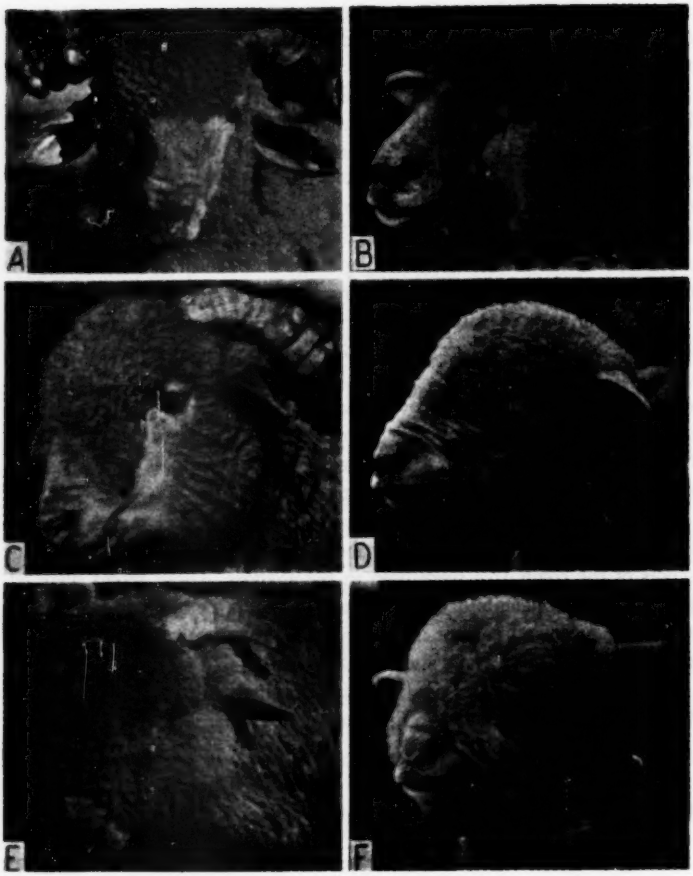

Figure 1. Face covering of weanling Rambouillet lambs. A and B, open face with score of 3 for ram and ewe lamb; C and D, partially-covered face with score of 4 for ram and ewe lamb; E and F, covered face with score of 5 for ram and ewe lamb.

face covering and neck folds, because in each case the mean square between sires was significantly greater than that within sires. This indicates that both traits were highly heritable.

The analyses of variance and covariance for the 892 dams and their offspring are summarized in table 2. Significant differences between sires for

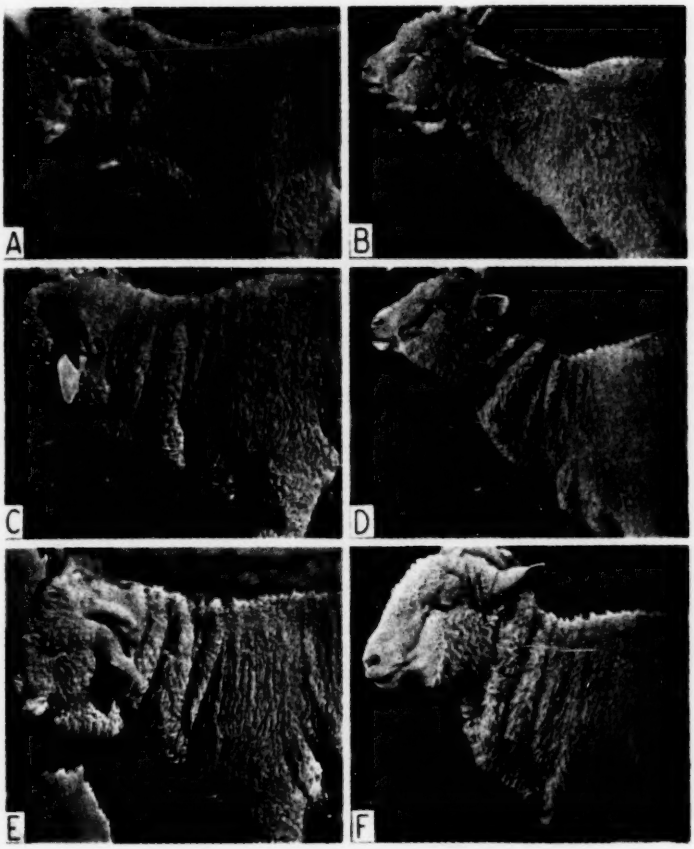

Figure 2. Neck folds in weanling Rambouillet lambs. A and B, Smooth necks with score of 1 for ram and ewe lamb; C and D, trace of neck folds with score of 2 for ram and ewe lamb; E and F, moderate neck folds with score of 3 for ram and ewe lamb.

both traits and both dams and offspring were found in the inbred lines. This shows definite line differences for each trait. Differences between sires in top crosses were significant for the offspring in 1 of the 2 years for each trait. Again this reflects the relative high heritability of these traits.

Two of the inbred lines were originally selected for open face and the offspring from these two lines had more open faces than the remainder of

TABLE 1. MEAN SQUARES FOR FACE-COVERING SCORES OF 2069 LAMBS AND NECK-FOLDS SCORES OF 2183 LAMBS

Group	Year	Source of variation	Face covering			Neck folds		
			Degrees of freedom	Mean squares	Constants[1]	Degrees of freedom	Mean squares	Constants[1]
One-sire inbred lines	1941	Total	661	0.2854	k=18.31	698	0.6829	k=18.83
		Between sires	34	1.3682**	f'= .025	36	2.3135**	f'= .026
		Within sires	627	.2267	f= .070	662	.5942	f= .066
	1942	Total	832	.3594	k=23.80	909	.6445	k=24.47
		Between sires	34	1.6574**	f'= .036	36	2.4755**	f'= .041
		Within sires	798	.3041	f= .078	873	.5690	f= .076
Top crosses	1941	Total	304	.2424	k= 9.81	304	.4711	k= 9.81
		Between sires	30	.5418**	f'= .054	30	.7742*	f'= .054
		Within sires	274	.2096	f= 0	274	.4380	f= 0
	1942	Total	268	.4171	k= 9.22	268	.5306	k= 9.22
		Between sires	28	.9004**	f'= .053	28	1.3000**	f'= .053
		Within sires	240	.3607	f= 0	240	.4408	f= 0

* Probability of chance occurrence <.05.

** Probability of chance occurrence <.01.

[1] k=effective number of offspring per sire. Since all of the sires did not have the same number of lambs, k is slightly smaller than the average number of lambs per sire. The formula used for figuring k is $=(\Sigma k)^2 - \Sigma(k)^2 / \Sigma k(n-1)$.

f'=average inbreeding coefficient of sires and dams in the inbred lines and of sires only in top crosses.

f=average inbreeding coefficient of offspring.

TABLE 2. MEAN SQUARES AND COVARIANCES FOR FACE-COVERING AND NECK-FOLDS SCORES OF 892 DAMS AND THEIR OFFSPRING

Group	Year	Source of variation	Degrees of freedom	Face-covering score			Neck-folds score			Constant
				Dams	Offspring	Cross-products	Dams	Offspring	Cross-products	
One-sire inbred lines	1941	Total	194	0.3580	0.3691	0.1260	0.5069	0.6761	0.0994	f'=0.036
		Between sires	31	.6114**	.9273**	.2609	1.1353**	1.9645**	.2733	f=0.097
		Within sires	163	.3098	.2630	.1004	.3874	.4311	.0663	
	1942	Total	411	.4185	.4575	.1343	.4684	.6256	.1040	f'=0.048
		Between sires	33	1.6865**	1.9466**	.4663	1.0567**	1.6403**	.5057	f=0.101
		Within sires	378	.3078	.3275	.1053	.4170	.5370	.0689	
Top crosses	1941	Total	119	.3338	.2041	.0973	.4957	.5286	.1279	f'=0.054
		Between sires	26	.3567	.2158	.0400	.3272	.8906**	.0213	f=0
		Within sires	93	.3274	.2008	.1133	.5428	.4273	.1577	
	1942	Total	164	.4597	.4225	.1084	.4934	.5609	.1241	f'=0.053
		Between sires	28	.3027	.9369**	.2575	.4739	.7883	.1115	f 0
		Within sires	136	.4920	.3166	.0777	.4975	.5141	.1268	

** Probability of chance occurrence <.01.

the lines. Therefore, the 114 lambs from these two lines were excluded from the analyses for face-covering score by the half-sib method because they tended to increase sire differences as a result of the selection which had been

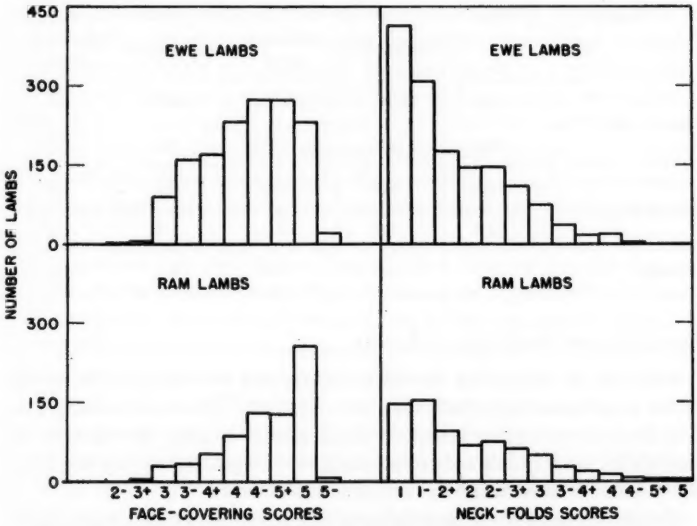

Figure 3. Distributions of unadjusted face covering and neck-folds scores for 1449 ewe lambs and 734 ram lambs at weaning age.

practiced. They were included in the daughter-dam comparisons as the inheritance of face covering within lines initiated with selected sheep should not differ greatly from those initiated with unselected animals.

Estimates of heritability were calculated from the data in tables 1 and 2 according to the formulas presented by Hazel and Terrill (1945b). These estimates with their standard errors are presented in table 3 for face-covering score and in table 4 for neck-folds score. Averages were calculated by weighting each of the individual estimates by the reciprocal of its squared standard error.

The average estimate of heritability of face covering was 0.56 ± 0.05 and of neck folds was 0.39 ± 0.05. No consistent differences were found in the individual estimates between groups or years, and the extreme estimates for each trait were not significantly different. The method of estimating heritability by the intra-sire regression of offspring on dam gave slightly higher estimates for each trait than did the half-sib method but again the differences were not significant.

TABLE 3. ESTIMATES OF HERITABILITY AND STANDARD ERRORS FOR FACE-COVERING

Group	Year	Half-sib method		Intra-sire regression method	
		Heritability	Standard error	Heritability	Standard error
One-sire inbred lines	1941	0.623	0.136	0.686	0.161
	1942	.433	.106	.719	.118
Top crosses	1941	.528	.199	.692	.146
	1942	.530	.199	.316	.135
Average		.511	.072	.603	.069

Discussion and Application of Results

Estimates of heritability should be interpreted according to the nature of the population from which they were obtained. This is particularly true if a flock is undergoing relatively rapid genetic change. An estimate of heritability is applicable only to populations with genetic makeup similar to the population from which the estimate was obtained.

Earlier estimates of the heritability of face covering (Terrill, 1941; Terrill and Hazel, 1943) were 0.44 and 0.32, respectively, which are somewhat lower than the estimate of 0.56 given here. These probably indicate that heritability of face covering decreases from weanling to yearling age, but

TABLE 4. ESTIMATES OF HERITABILITY AND STANDARD ERRORS FOR NECK-FOLDS

Group	Year	Half-sib method		Intra-sire regression method	
		Heritability	Standard error	Heritability	Standard error
One-sire inbred lines	1941	0.384	0.104	0.382	0.194
	1942	.330	.087	.369	.137
Top crosses	1941	.276	.158	.581	.175
	1942	.663	.217	.510	.169
Average		.362	.070	.451	.082

it may also indicate that heritability of face covering was increasing in this flock, since the smaller estimates occurred in earlier years. Further selection for open face is almost certain to increase the genetic variability of face covering over that indicated in figure 3. Of course, it is possible that this may result in only slight, if any, further increase in heritability. Further studies with Targhee, Columbia and Corriedale breeds (Hazel and Terrill, 1946b) show lower estimates of heritability. In these breeds it is probable that genetic variability may be decreasing as the genes for open face are becoming fixed.

Peters (1945) found parent-offspring correlations for face covering of Rambouillet weanling lambs to range from −0.04 to 0.44. An approximate estimate of heritability from his correlations is consistent with that reported here.

It is probable that heritability of neck folds is decreasing in this flock as the genes for smoothness become fixed or increase in frequency. It is reasonable that genetic variability is decreasing while other sources of variability of neck folds probably remain constant or decrease in effect at a slower rate. This may partly explain the higher estimate of heritability of 0.51 (Jones *et al.*, 1946) in a flock of Rambouillets which appear to have more skin folds and therefore greater variability for folds than the flock studied in this paper. Jones *et al.* (1946) based their estimate on a total score for folds over the entire body but showed further that the neck region might be used with a high degree of reliability to replace the record of the entire animal. Further studies at Dubois (Hazel and Terrill, 1946b) with Targhee, Columbia and Corriedale lambs show decreasing estimates of heritability as the breeds become more smooth.

Other heritability estimates for skin folds in Rambouillets were obtained by Madsen *et al.* (1943). An estimate of 0.5 was obtained from their data by doubling the regression coefficient of daughters at 6 months on dams after shearing. With the small numbers involved (52 pairs) this coefficient was not significant. They found highly significant correlations between scores at weaning and at other ages indicating that effective selections could be made at weaning time.

Terrill and Hazel (1943) reported estimates of 0.26 and 0.32 for neck and body folds, respectively, in yearling Rambouillet ewes. These estimates were based on intra-sire, daughter-dam regressions, but corrections for inbreeding were not made. Therefore, the true estimates would be somewhat higher than those presented, but it is likely that the heritability at yearling age would be lower than at weanling age.

Both face covering and neck folds are highly heritable when compared with other traits in weanling Rambouillets. Hazel and Terrill (1945b,

1946a) reported estimates of 0.40, 0.30, 0.13 and 0.04 for staple length, body weight, body type and condition, respectively.

High heritability of face covering indicates that rapid progress toward open face can be made by selection on phenotypic merit at weaning time. By using ram lambs in breeding, anv gain made in 1 year may be taken advantage of immediately through the sire. Progeny test information should be considered if and when available, but to insist that rams be tested before they are used extensively would impede the rate at which face covering could be changed. Inasmuch as it has considerable economic importance, open face should be emphasized in selecting lambs, and attention to less heritable and less valuable traits be deferred until more information has been obtained.

Reports from the literature indicate that in some flocks the heritability of neck folds is as high as that of face covering in the flock studied here, and in those cases breeding recommendations similar to those for face covering would apply. Considerable progress has already been made in this flock toward the elimination of folds, and it is rapidly nearing the point where further elimination of folds will be of minor importance. Thus less attention will be given to folds in weanling selections. If the apparent decrease in heritability is real, and in view of the tentative proposition by Jones *et al.* (1946), that smoothness is due to dominant genes, emphasis on progeny test information will be necessary to reduce further the frequency of genes causing folds.

Summary

Estimates of heritability of face covering and neck folds as evaluated by scoring were calculated from data on 2183 weanling Rambouillet lambs born in 1941 and 1942 and 892 dam-offspring pairs. Two breeding methods had been followed consisting of inbred lines and top crosses. Estimates based on daughter-dam regressions and half-sib correlations were calculated for each year and breeding method, making eight individual estimates for each trait.

Average heritability estimates of 0.56 ± 0.05 for face covering and 0.39 ± 0.05 for neck folds were obtained. No significant differences were found between estimates for years, breeding methods or methods of estimation. Significant variations between inbred lines were found for each trait.

The interpretation of these estimates of heritability in relation to the populations from which they were obtained and their application to breeding programs are discussed.

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THE INFLUENCE OF HIGH-PROTEIN AND LOW-PROTEIN-HIGH-STARCH DIETS ON BLOOD GLUCOSE AND ACETONE BODIES OF PREGNANT EWES[1]

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A STUDY of the blood picture prior to and during the development of ketosis in dairy cows suggested that the causative factors were operative prior to parturition, although the condition did not develop until after parturition (Shaw, 1943). In a search for the factors responsible for the development of ketosis in dairy cattle, a study is being made of the effect of the quality and quantity of the feed upon the ability of the animal to maintain a normal level of blood sugar and acetone bodies during the period when susceptibility to ketosis is greatest. In the case of the cow, this period is immediately following parturition; in the ewe it appears to be in the latter stage of pregnancy. As ketosis in sheep appears to be quite similar to that observed in cattle, studies on pregnant ewes were included in the general project.

In a study on rats, MacKay *et al.* (1941) were able to show that the rapidity of onset and the degree of ketosis reached during fasting bears an inverse relationship to the protein content of the preceding diet. In rather extensive experiments Fraser *et al.* (1938, 1939) and Groenewald *et al.* (1941) produced a ketosis in ewes by maintaining very low levels of energy intake over a period of time and by complete fasting. Fat ewes were more susceptible to ketosis than thin ewes. Ewes carrying two or more lambs were more susceptible than ewes carrying only one lamb. Ketosis developed in barren ewes only after extended periods of inanition. The former workers were unable to detect any difference in the degree of fasting ketosis produced in ewes which had received daily intakes of 0.086 pound of "protein equivalent" from that produced in ewes which had received 0.154 pound of "protein equivalent" per ewe. They also reported that starch was just as efficient in promoting recovery from ketosis as flaked maize or a protein-rich meals mixture. On the other hand, the latter workers concluded that the symptoms were more severe in the group of ewes which received a sugar supplement than in the case of the group which received the protein supplement. The present study was designed to determine whether pregnant ewes could be rendered more susceptible to the development of ketosis by the feeding of low protein diets.

[1] This project was financed in part by a grant from the Eastern States Farmers' Exchange.
[2] Departments of Dairy Industry and Animal Husbandry, Storrs, Connecticut.

Experimental Procedure

Sixteen pregnant mature Dorset ewes were divided into four groups of four each as evenly as possible on the basis of body weight. Two groups were maintained on a high protein diet for a period of 83 days, which was approximately three weeks prior to the expected date of parturition for most of the ewes. At this time the energy intake of one group was decreased to approximately 70 percent of requirements for one week and then decreased to 50 percent for the remainder of the period. The other two groups were fed a low protein, high starch diet and the feed intake of one of these groups was decreased to parallel the high protein, low energy group. The remaining low protein, high starch group was fed at a higher level to parallel the high protein group fed at the higher level after the 83rd day. During the first 83 days all groups were fed alike by limiting the food intake to that of the group consuming the least.

As the average weights of the four groups were approximately the same at the beginning, no attempt was made to compensate for later differences.

The hay intake was limited to 1.63 pounds daily per ewe during the first 83 days and to 1.75 pounds daily during the remainder of the experiment in order to induce the ewes to eat more of the concentrate mixtures.

One ewe in the high protein, low energy group died on the 67th day of the experiment due at least in part to inanition as the result of a failure to eat as much as the others. One ewe in the low protein, low energy group was removed from the experiment 93 days after the beginning of the experiment when it was found to be non-pregnant.

The ewes were weighed on three consecutive days at the beginning of the experiment and on the 75th and 93rd days of the experiment. Blood glucose and acetone bodies were determined at frequent intervals, the length of such intervals decreasing towards the termination of pregnancy and being continued until a week after parturition. The methods used for blood glucose and acetone bodies were described previously (Shaw, 1943).

The concentrate mixtures used are shown in table 1 and the analyses of the two mixtures and the hay in table 2. The hay was a low grade mixed hay with a predominance of timothy. The digestible protein and total digestible nutrients were calculated from Morrison's digestion coefficients.

Experimental Results and Discussion

The original plan of the experiment was to feed heavily in order to fatten the ewes during the earlier stage of the experiment. However, as will be noted in tables 3 and 4, the energy intake was only slightly greater than the calculated requirements during the first two months. Towards the end

TABLE 1. CONCENTRATE MIXTURES USED IN EXPERIMENT

Contents of ration	High protein concentrate	Low protein concentrate
	lbs.	lbs.
Yellow corn meal	990	990
Crimped oats	600	600
Casein	360	—
Corn starch	—	360
Minerals, salt, and yeast*	50	50
Total	2000	2000

* Composed of 10 lbs. of calcium carbonate, 20 lbs. of dicalcium phosphate, and 20 lbs. of salt to which was added 0.25 lbs. of irradiated yeast.

of the experiment even the high energy groups consumed somewhat less than the calculated requirements, the total consumption of all groups during the 83 days and of the high energy groups in the latter period being limited by the poor appetite of the ewes on the low protein diet.

The ewes in the high protein, low energy group were on a limited intake of approximately 50 percent of requirements for 8, 17, and 19 days before

TABLE 2. ANALYSES OF THE FEEDS USED, EXPRESSED IN PERCENTAGES

Feed	Crude protein	Crude fiber	Nitrogen free extract	Ether extract	Digestible crude protein	Total digestible nurients
High protein concentrate	24.10	5.30	51.35	3.25	22.34	76.89
Low protein-high starch concentrate	8.30	5.25	67.10	3.25	6.37	76.80
Hay	6.50	34.00	46.00	2.00	2.81	48.99

parturition, whereas the low protein, low energy group was fed at this level for 16, 21, and 45 days prior to parturition. Both groups were maintained at this low level until one week following parturition, even though the energy requirements increased at this time.

It will be noted from tables 3 and 4 that the protein intake of the two low protein groups was less than the calculated requirements during the entire experiment, being less than 80 percent during most of the experiment and decreasing to less than 40 percent for the low energy group during the period of limited feeding.

The low protein groups gained less than the high protein groups, the low protein, low energy group actually losing weight during the latter part of the period.

The high protein, low energy group gained more than the high protein, full fed group contrary to what would have been expected. The greater gain may have been due in part to the fact that the ewes lambed at an earlier

TABLE 3. MEAN BODY WEIGHTS AND CALCULATED NUTRIENT REQUIREMENTS[1]

Days	High protein group, 4 ewes			High protein-low energy group, 3 ewes			Low protein group, 4 ewes			Low protein-low energy group, 3 ewes		
	Av. wt.	Nutrient req.		Av. wt.	Nutrient req.		Av. wt.	Nutrient req.		Av. wt.	Nutrient req.	
		D.P.[2]	T.D.N.[3]		D.P.	T.D.N.		D.P.	T.D.N.		D.P.	T.D.N.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1	111	0.185	1.75	112	0.185	1.75	110	0.185	1.75	115	0.190	1.80
75	140	0.215	2.05	147	0.225	2.20	137	0.210	2.00	139	0.215	2.05
93	145	0.270	2.50	156	0.280	2.65	140	0.265	2.45	138	0.265	2.45

[1] Calculated according to standards of Morrison (1939).
[2] Digestable protein.
[3] Total digestible nutrients.

date, one ewe lambing from two to four weeks earlier than the ewes in the other group.

All of the ewes in the low protein, low energy group were carrying two lambs. One ewe in each of the remaining three groups gave birth to single lambs, the remaining ewes having twin lambs.

The data obtained on blood glucose are presented graphically in figure 1.

TABLE 4. AVERAGE DAILY INTAKE OF NUTRIENTS

Days	High protein group		High-protein low energy group		Low protein group		Low protein-low energy group	
	D.P.	T.D.N.	D.P.	T.D.N.	D.P.	T.D.N.	D.P.	T.D.N.
	lbs.!	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1–10	0.468	2.25	0.468	2.25	0.167	2.25	0.167	2.25
11–20	0.477	2.28	0.477	2.28	0.169	2.28	0.169	2.28
21–30	0.476	2.28	0.476	2.28	0.168	2.28	0.168	2.28
31–40	0.507	2.38	0.507	2.38	0.177	2.38	0.177	2.38
41–50	0.549	2.53	0.549	2.53	0.189	2.53	0.189	2.53
51–60	0.549	2.53	0.549	2.53	0.189	2.53	0.189	2.53
61–70	0.456	2.21	0.456	2.21	0.163	2.21	0.163	2.21
71–82	0.493	2.34	0.493	2.34	0.173	2.33	0.173	2.33
83–92	0.419	2.13	0.217	1.43	0.153	2.11	0.097	1.43
92–101	0.407	2.09	0.161	1.24	0.160	2.18	0.081	1.24
102–111	0.407	2.09	0.161	1.24	0.145	2.01	0.081	1.24
112–	0.384	2.01	0.161	1.24	0.145	2.01	0.081	1.24

The curves for blood glucose and acetone bodies are quite similar in all groups and do not suggest any relationship between the level of these two substances and the protein content of the diet even in the limited fed groups. The decrease in blood glucose which occurred rather uniformly in all groups following parturition is of particular interest as a similar decrease has frequently been observed in cows.

In evaluating the results of this experiment, any general conclusions must apply only to ewes maintained at a level of energy intake not greatly exceed-

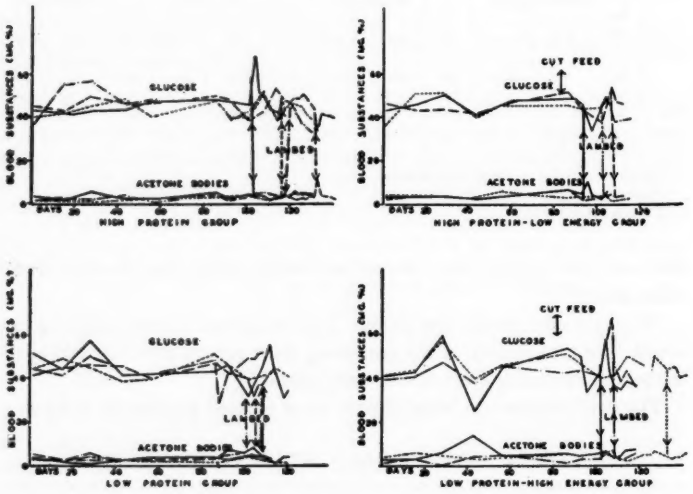

Figure 1. Blood analyses of animals on high and low protein diets.

ing the actual requirements. Had the ewes been fattened during the earlier part of the experiment the results might have been different. It is of interest that MacKay *et al.* (1941) have reported that the degree of ketosis on high and low protein diets was not related to the fat content of the liver. They suggested that the antiketogenic effect of the previous high protein diet was due to protein storage. Considering the low level of protein intake there could have been little protein storage on the low protein diets, yet ketosis did not develop. Field observations on both ewes and cows, however, have indicated that ketosis developed most frequently in animals in good condition. Likewise, the experiments of Fraser, *et al.* (1938, 1939) show

quite clearly that fat ewes are much more susceptible. Possibly the period of under feeding was of insufficient length and severity. In any event, a low protein diet alone does not appear to be sufficient to produce ketosis in pregnant ewes. It might be pointed out that the protein intake of the so-called adequate protein group of Fraser, *et al.* (1938), which was compared with another group on a lower protein intake and similarly fasted, actually received less protein than the amount recommended by Morrison (1939). In the experiments by Groenewald, *et al.* (1941) when the ewes were changed to the high and low protein diets, the feed proved so unpalatable that they ate very little. The latter experiments, therefore, do not provide data on the possible relationship of the protein content of the preceding diet to the degree of ketosis reached during fasting. Further experimentation appears advisable in which the protein content of the previous diet should be higher and in which the diets are sufficiently palatable to fatten the ewes. The degree of fasting should also be more severe than in the experiments herein recorded in order to insure that some degree of ketosis will be produced.

There appears to be some question as to whether the decrease in blood glucose observed in cows following parturition (Godden and Ollcroft, 1941) is a normal physiological phenomenon. Studies at this station have shown that the blood glucose of some individuals, at least, is maintained at a relatively high level following parturition. The decrease in the blood glucose in all groups following parturition, but not before, was somewhat surprising in view of the fact that ketosis in the ewe is most prevalent during the latter period of pregnancy. The decrease in blood glucose which occurred following parturition would appear to be due to the increased energy demands of milk secretion. It may be that the low incidence of ketosis following parturition in ewes under field conditions reflects a general farm practice of maintaining a higher plane of nutrition at this time. If such is not the case, it is difficult to avoid the suggestion that something other than a deficiency of energy alone is responsible for the fact that the incidence of ketosis in ewes under farm conditions is highest in the latter part of pregnancy.

Conclusions

Ewes maintained on a low protein diet for approximately 100 days prior to parturition did not develop hypoglycemia or ketonemia during the period of pregnancy even when the energy intake was limited to 50 percent of requirements. However, a mild hypoglycemia did develop following parturition in both the high and the low protein groups.

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A PROPOSED METHOD OF MEASURING PASTURE YIELDS WITH GRAZING CATTLE[1]

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METHODS of measuring pasture yields with grazing animals have received much attention and have been standardized and summarized by joint committees of the American Society of Agronomy, the American Dairy Science Association and the American Society of Animal Production (Lush, *et al.*, 1943). As suggested in this summary, minor details of technique in pasture investigations must be adjusted to fit the local conditions and the problems under investigation. This paper describes an adaptation of this recognized technique which is being used for determining the yield of pasture grass by grazing cattle at the Everglades Experiment Station.

The measurements proposed are based on averages and are intended primarily to help solve two problems. The first is to obtain a measure for a comparison of several grass varieties grazed rotationally throughout the 12 months grazing period of southern Florida. The second is to find out within reasonable accuracy how much grass steers will consume while fattening on pasture with measured amounts of added concentrates. These measurements are recognized to be less accurate than obtained by the methods of Garrigus (1939) and do not include some of the other known variables such as the associative effects of supplementary feeds on the coefficients of digestibility or the efficiency of utilization of feed nutrients on different levels of intake as indicated by animal performance, such as rate of gain.

Maintenance Requirement of Cattle in Total Digestible Nutrients

While several investigators have made studies of the nutrient requirement of cattle for maintenance, the Morrison (1936) feeding standards are generally accepted as a practical guide for feeding practices. These are based on an allowance of 7.93 lbs. of total digestible nutrients for the maintenance of a 1000 lb. cow and the requirement for maintenance of cattle of other weights proportional to the 0.73 power of the live weight. Since the 0.73 power of 1000 is 154.9, this divided by 7.93, the maintenance requirement of a 1000 lb. cow, gives the factor 19.53. From this, the maintenance requirement in T.D.N. for animals of any weight can be determined by the formula:

[1] Contribution from the Animal Husbandry Section, Everglades Experiment Station, Belle Glade, Florida, Published with permission of the Director, Florida Agricultural Experiment Station.

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$$\frac{W^{0.73}}{19.53} = \text{T.D.N.}$$

in which W is the average live weight of the animal and T.D.N. the average daily maintenance requirement for an animal of this weight. The maintenance requirement, computed by this method, for animals of various weights less than 1000 pounds is shown in table 1.

Since feeding experiments and grazing trials in Florida have been conducted with cattle weighing less than 1000 pounds, this method of calculating daily maintenance requirement more nearly expresses a measure for Florida conditions than to apply the 1000 pound rate of 0.8 pound of total digestible nutrients per 100 pounds live weight.

TABLE 1. DAILY MAINTENANCE REQUIREMENTS OF TOTAL DIGESTIBLE NUTRIENTS FOR CATTLE OF VARIOUS WEIGHTS

Live weight of animal (w)	$W^{.73}$	Daily requirement of T.D.N.	T.D.N. per 100 lbs. live weight
pounds		*pounds*	*pounds*
1000	154.9	7.93	.77
900	143.4	7.34	.81
800	131.6	6.74	.84
700	119.4	6.11	.87
600	106.7	5.46	.91
500	93.4	4.78	.96
400	79.3	4.05	1.01

Nutrient Requirement for Gain in Weight

Accepted factors in terms of digestible nutrients for change in live weight were proposed by Knott and associates (1934) and have been summarized by Lush (1943) as 3.53 pounds of total digestible nutrients for each pound gain, and a deduction of 2.73 pounds of total digestible nutrients for each pound loss in weight.

To determine how closely these factors applied to cattle in Florida, a study has been made of three steer feeding experiments reported in Florida Experiment Station Bulletins numbers 320, 358 and 360, conducted at Quincy, Gainesville and Belle Glade respectively. (Shealy and Gratz, 1938; Shealy, Kirk and Crown, 1941; Kidder and Kirk, 1941.) A summary of this study is presented in table 2.

These records show that the nutrient requirements for gains can be expected to vary in different lots of cattle, different rations and during differ-

TABLE 2. TOTAL DIGESTIBLE NUTRIENT REQUIREMENT OF FLORIDA STEERS PER POUND GAIN

Results at Quincy (Shealy and Gratz, 1938)

Items compared	1934–35				1935–36				1936–37			
	Lot 1	Lot 2	Lot 3	Lot 4	Lot 1	Lot 2	Lot 3	Lot 4	Lot 1	Lot 2	Lot 3	Lot 4
Av. daily intake T.D.N. (lbs.)	11.19	11.68	10.63		11.63	13.22	12.55	12.81	12.78	12.54	12.45	12.85
Av. initial and final wt. per steer (lbs.)	634.	621.	640.		580.	592.	613.	582.	651.	639.	667.	637.
T.D.N. Maintenance $\frac{W^{.73}}{19.53}$ (lbs.)	5.68	5.59	5.72		5.32	5.40	5.54	5.34	5.79	5.71	5.90	5.69
T.D.N. gain (lbs.)	5.51	6.09	4.91		6.31	7.82	7.00	7.47	6.09	6.83	6.55	7.16
Av. daily gain (lbs.)	1.73	1.93	1.94		1.89	1.91	2.15	1.86	1.83	1.53	1.83	1.80
T.D.N. per pound gain (lbs.)	3.18	3.16	2.53		3.34	4.09	3.26	4.02	3.82	4.46	3.58	3.98

Results at Gainesville (Shealy, Kirk and Crown, 1941)

	1934–35				1935–36				1937–38			
Av. daily intake T.D.N. (lbs.)	10.97	12.21	10.82		11.97	13.33	11.56		11.36	12.96	11.28	
Av. initial and final wt. per steer (lbs.)	691.	700.	681.		700.	701.	686.		669.	679.	664.	
T.D.N. Maintenance $\frac{W^{.73}}{19.53}$ (lbs.)	6.06	6.11	5.99		6.11	6.12	6.02		5.91	5.97	5.88	
T.D.N. gain (lbs.)	4.91	6.10	4.83		5.86	7.21	5.54		5.45	6.99	5.40	
Av. daily gain (lbs.)	1.78	2.01	1.82		1.87	2.18	1.69		1.79	2.06	1.84	
T.D.N. per pound gain (lbs.)	2.76	3.12	2.47		3.13	3.31	3.28		3.04	3.39	2.93	

Results at Belle Glade (Kidder and Kirk, 1941)

	1936–37				1937–38				1938–39			
Av. daily intake T.D.N. (lbs.)	10.91	10.60	10.21	10.58	12.62	11.97	11.73	12.41	10.80	10.71	10.02	10.41
Av. initial and final wt. per steer (lbs.)	652.	655.	654.	657.	698.	689.	689.	704.	614.	598.	579.	601.
T.D.N. Maintenance $\frac{W^{.73}}{19.53}$ (lbs.)	5.80	5.82	5.82	5.84	6.10	6.04	6.04	6.14	5.56	5.45	5.32	5.47
T.D.N. gain (lbs.)	5.11	4.78	4.39	4.74	6.52	5.93	5.69	6.27	5.24	5.26	4.70	4.94
Av. daily gain (lbs.)	2.03	1.73	1.75	1.73	1.90	1.92	1.95	2.05	1.93	1.95	1.70	1.92
T.D.N. per pound gain (lbs.)	2.52	2.76	2.51	2.74	3.43	3.09	2.92	3.06	2.72	2.70	2.76	2.57

ent seasons. In the Quincy trials, 11 lots of steers showed an average requirement of 3.58 pounds of total digestible nutrients per pound gain. At Gainesville, the average requirement of 9 lots of steers was 3.05 pounds of total digestible nutrients per pound gain. At Belle Glade, in 12 lots of steers, the average requirement was 2.82 pounds of total digestible nutrients per pound gain. The average nutrient requirement per pound gain for these 330 steers in 32 lots at three experiment stations was 3.15 pounds of total digestible nutrients.

Since these calculations are based on the assumption that the average daily maintenance requirement of a 1000 pound animal is 7.93 pounds of total digestible nutrients, and this may not be an exact figure, the difference

TABLE 3. THE COMPOSITION, COEFFICIENTS OF DIGESTIBILITY OF THE NUTRIENTS AND DIGESTIBLE NUTRIENT CONTENT OF THE FEEDS USED IN THE EXPERIMENTS REPORTED BY KIDDER (1943)

Feed	Dry matter	Crude protein	Crude fiber	Nitrogen-free extract	Crude fat	Ash	Total digestible nutrients
	percent	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*
Ground snapped corn	89.85	8.85	10.02	67.28	2.67	1.69	—
Ground shallu heads	90.51	12.67	9.24	61.91	3.48	3.20	—
Cottonseed meal	89.71	41.93	13.52	24.71	3.11	6.44	—
Cottonseed cake	90.79	44.42	12.71	24.24	2.61	6.79	—
Molasses	80.20	9.01	0	63.99	0	7.20	—
Sugarcane	20.00	1.38	6.90	10.48	0.22	1.02	—
Pasture grass	18.19	2.73	5.40	8.20	0.52	1.34	—
Coefficients of digestibility							
Ground snapped corn	—	69	55	84	87	—	—
Ground shallu heads	—	76	52	91	87	—	—
Cottonseed meal	—	81	45	71	94	—	—
Molasses	—	32	—	90	—	—	—
Sugarcane	—	20	55	69	56	—	—
Pasture grass	—	65	68	70	58	—	—
Digestible nutrients							
Ground snapped corn	—	6.11	5.51	56.52	5.22	—	73.36
Ground shallu heads	—	9.63	4.80	56.34	6.82	—	77.59
Cottonseed meal	—	33.96	6.08	17.54	6.57	—	64.15
Cottonseed cake	—	35.98	5.72	17.54	5.51	—	64.35
Molasses	—	2.88	—	57.59	—	—	60.47
Sugarcane	—	2.76	3.80	7.23	0.28	—	14.07
Pasture grass	—	1.78	3.67	5.74	0.68	—	11.87

between 3.15 and 3.53 is not excessive. Environmental conditions could account for the differences between the three Florida experiments. Materials used for bedding should also be considered. However, it is usually assumed that consumed bedding contains only sufficient nutrients for its own digestion. For these reasons, while the factor 3.53 may be slightly high for Florida conditions it seems satisfactory for practical purposes, and has been accepted by recognized authorities, (Lush, *et al.*, 1943).

Calculating the Amount of Grass Consumed by Grazing Cattle

Experiments in fattening steers on pasture with supplementary concentrates have been completed at the Everglades Station and reported by Kidder (1943). In this experiment all concentrate feeds were weighed and composite samples analyzed, but no weight record of grass consumed was possible.

Average composition, coefficients of digestibility and digestible nutrient content of the feeds used in this experiment, including grass, are shown in table 3. Digestion coefficients for milo head chops given by Morrison (1936) are used for the ground shallu heads. Coefficients for cottonseed meal and molasses were also obtained from Morrison (1936). The coefficient used for ground snapped corn is from Shealy and associates (1941) and for sugarcane from Neal (1940). Digestion coefficients for Napier grass leaves (Kidder, 1945) are used for the pasture grass.

An inverse method of computing the amount of grass consumed by the steers in these fattening trials is shown in table 4. Average daily consumption of nutrients in the supplementary feeds is computed from the feeding records and the data in table 3. The performance of the steers is determined by adding the maintenance requirement through the formula $\frac{W^{0.73}}{19.53}$ T.D.N. to an allowance of 3.53 pounds of total digestible nutrients per pound gain. From this daily nutrient requirement, based on the average size of the steer and the average daily gain, the known nutrient contents of supplementary feeds are deducted leaving the nutrient content of the grass obtained by the steer. From these data and the nutrient content of the grass, it was determined that each steer in lots I and II consumed an average of approximately 27 pounds of grass daily, while each steer in lot III, on a limited concentrate ration, consumed an average of 59 pounds of grass daily.

In rotational grazing trials at the Everglades Station annual grass yield determined by animal performance in this manner have shown 92,200 pounds

TABLE 4. INVERSE METHOD OF CALCULATING GRASS CONSUMED BY STEERS IN EXPERIMENTS REPORTED BY KIDDER (1941)

Items compared	T.D.N.	1939–40			1940–41			1941–42		
		Lot 1	Lot II	Lot III	Lot I	Lot II	Lot III	Lot I	Lot II	Lot III
	percent	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*
Average daily ration:										
Ground snapped corn	—	5.21	—	—	4.98	—	—	4.41	—	—
Ground shallu heads	—	—	5.21	—	—	4.98	—	—	4.41	—
Cottonseed meal	—	2.00	2.00	—	1.97	1.97	—	2.00	2.00	—
Cottonseed cake	—	—	—	2.00	—	—	1.97	—	—	2.00
Molasses	—	5.21	5.21	—	4.98	4.98	—	4.39	4.39	—
Sugarcane	—	2.80	2.80	5.27	—	—	—	1.94	1.94	5.58
Pasture grass*	—	26.79	20.39	52.82	23.25	23.76	65.63	33.28	38.67	59.14
Average daily ration T.D.N.										
Ground snapped corn	73.36	3.82	—	—	3.65	—	—	3.24	—	—
Ground shallu heads	77.59	—	4.04	—	—	3.86	—	—	3.42	—
Cottonseed meal	64.15	1.28	1.28	—	1.26	1.26	—	1.28	1.28	—
Cottonseed cake	64.35	—	—	1.29	—	—	1.27	—	—	1.29
Molasses	60.47	3.15	3.15	—	3.01	3.01	—	2.65	2.65	—
Sugarcane	14.07	.39	.39	.74	—	—	—	.27	.27	.79
Total supplement to pasture	—	8.64	8.86	2.03	7.92	8.13	1.27	7.44	7.62	2.08
Pasture grass	11.87	3.18	2.42	6.27	2.76	2.82	7.79	3.95	4.59	7.02
Av. initial weight per steer	—	545	530	533	587	581	597	727	725	708
Av. final weight per steer	—	763	733	639	749	753	707	884	908	798
Av. weight per steer	—	654	632	586	668	667	652	806	817	753
Av. daily gain per steer	—	1.70	1.59	.83	1.35	1.43	.92	1.31	1.52	.75
$\frac{W.^{.75}}{19.53}$ T.D.N. for maintenance	—	5.82	5.67	5.37	5.91	5.90	5.81	6.77	6.84	6.45
T.D.N. for gains ($X3.53$)	—	6.00	5.61	2.93	4.77	5.05	3.25	4.62	5.37	2.65
Av. daily intake T.D.N.	—	11.82	11.28	8.30	10.68	10.95	9.06	11.39	12.21	9.10
T.D.N. in supplements fed	—	8.64	8.86	2.03	7.92	8.13	1.27	7.44	7.62	2.08
T.D.N. in grass consumed	—	3.18	2.42	6.27	2.76	2.82	7.79	3.95	4.59	7.02
$\frac{\text{T.D.N.}}{.1187}$ Av. daily grass consumed		26.79	20.39	52.82	23.25	23.76	65.63	33.28	38.67	59.14

* Calculated from animal performance and nutrient content of grass.

of grass per acre, which on a basis of 19 percent dry matter is 17,500 pounds of dry matter. This compares favorably with clipped yields shown by Neller (1939) in which as high as 21,900 pounds of grass per acre on an oven dry basis were obtained in one year.

Summary

A proposed adaptation of the indirect method of measuring pasture yields with grazing cattle is described. This is based on the assumption that the average total digestible nutrient requirement for maintenance of a 1000 pound cow is 7.93 pounds of total digestible nutrients per day and that the average daily maintenance requirement for animals of other weights

is proportional to the 0.73 power of the live weight. From this proportion it is shown that the average requirement for daily maintenance of animals of any weight can be calculated by the formula $\frac{W^{0.73}}{19.53} = \text{T.D.N.}$

An analysis of the records of three Florida steer feeding experiments by this method shows that 330 steers consumed an average of 3.15 pounds of total digestible nutrients for each pound gain in live weight. Since the accepted factor for gain in weight is 3.53 pounds of total digestible nutrients, this would indicate either that the maintenance requirement for Florida cattle is slightly less than the assumed values or that environmental conditions were favorable. Associative effects of feeds on coefficients of digestibility may have influenced these results.

In an analysis of another Florida steer feeding experiment using this method of calculating the total digestible nutrient requirements for maintenance and gains and deducting the nutrient content of supplementary feeds, the amount of grass consumed by the steers has been closely estimated. This shows that steers on a limited concentrate ration consumed an average of 59 pounds of grass while those receiving as much concentrate as they would clean up consumed only 27 pounds of grass each daily.

Yields of grass obtained through calculations of animal performance, in the manner herein described, are within the range of annual yields of grass previously reported from this Station by Neller (1939).

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BIOTIN DEFICIENCY SYNDROME IN PIGS FED DESICCATED EGG WHITE[1]

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WILLMAN *et al.* (1942) reported that satisfactory gains were made by 50-pound hogs fed incubated eggs, yellow corn, and salt. Their work showed that raw incubated eggs were digested as efficiently by the hog as cooked incubated eggs. Boas (1927) was the first to report that rats receiving dried egg white as the dietary source of protein developed a syndrome with the chief symptoms being a characteristic eczematous dermatitis accompanied by alopecia, blepharitis, spasticity, and in some cases edema of the feet. Gyorgy (1939), Sullivan and Nicholls (1941, 1942), and Nielsen and Elvehjem (1942) showed that this syndrome in that rat could be cured by the addition of biotin or biotin rich preparations. Eakin *et al.* (1940, 1941) showed that egg white contains a protein called "avidin" which substance plus biotin forms a non-absorbable biotin-avidin complex in the intestinal tract (Gyorgy *et al.*, 1941 and Gyorgy and Rose, 1941). Thus, the animal is unable to utilize whatever biotin it obtains in the ration or that which is synthesized in the intestinal tract when avidin is present in high enough levels in the diet.

The experiment which is herein reported was undertaken to determine whether the avidin in egg white will tie up the biotin in the intestinal tract of the pig as it does with the rat, dog, rabbit, monkey, man, and chick (Rosenberg, 1945). This work is of particular interest from a practical stand point, since many persons have inquired at this experiment station regarding the feeding value of raw spoiled eggs and whether any harmful effect might result from feeding them to hogs.

Experimental

The pigs used in this experiment had been fed on a purified ration (sucrose 57.7, casein 26.1, lard 11.0, and mineral mix 5.2 percent) for 16 weeks sub-

[1] Published as Scientific Paper No. 655. College of Agriculture and Agricultural Experiment Station, State College of Washington, Pullman.

[2] Department of Animal Husbandry. The authors are indebted to Swift & Company, Chicago, Illinois, for supplying the desiccated egg white used in this trial, and especially for the cooperation of R. C. Newton, Vice President, and H. S. Mitchell, Chief Chemist. Merck & Company, Rahway, New Jersey, supplied biotin and other B-complex vitamins for this work, and the interest and suggestions of Dr. D. F. Green have been very helpful. Dr. T. H. Jukes, Lederle Laboratories, supplied the mixed tocopherols and menadione. The Bio-Vita 10 MA Natural Shark Liver Oil blend containing 10,000 units of vitamin A per gram was supplied by R. T. Carruthers, Bioproducts, Inc., Astoria, Oregon.

At the end of the feeding trial, the steers were shipped to market (South St. Paul, or Chicago) at which time slaughter grades, carcass grades, and various carcass data were obtained. Slaughter and carcass grades on Agricultural Marketing Service Grading Forms were obtained by a committee of 3 men and the average of the 3 grades was used as a final grade.[2] Area of eye muscle was obtained by tracing a cross-section of the eye muscle (longissimus dorsi) on heavy wax impregnated paper. The area was obtained by the use of a planimeter on these tracings. The average scores, grades, dressing percentages, and areas of eye muscle are shown in table 1.

Data and Discussion

Since all animals each year were marketed at the same time there was considerable variation in the final weight between animals from different sires as well as between animals from the same sire. The writers also have shown (1946) that there was a significant difference in both final weight and in feed lot gain between sire progenies. Both of these factors have an effect on the grade of the slaughter steer and on the carcass grade. The steer that gains the most or weighs the most at the end of the feeding trial usually grades higher than a smaller steer of the same age. By covariance analysis (Snedecor, 1937) the following correlations within sire groups were found:

Items Correlated	r
Score at weaning and weaning weight	0.68
Slaughter steer grade and final feed lot wt.	0.64
Carcass grade and final feed lot weight	0.54
Area of eye muscle and final feed lot wt.	0.14

All correlations except area of eye muscle are highly significant and indicate that a substantial part of the variance in scores and grades is accountable to weight. Table 2 contains the intra-year analyses of variance (corrected for weight) for weaning score, slaughter grade, carcass grade, carcass yield and area of eye muscle. Significant differences were observed between sire groups in weaning score, slaughter steer grade, carcass grade, and area of eye muscle. Differences between sire groups in carcass yield (dressing percent) were not significant and indicate that this factor is largely of environmental control.

The mean squares were further analyzed into their theoretical components using the method described by Winsor and Clarke (1940). This is also shown in table 2. The fraction $\frac{B}{A+B}$ is the correlation between half-sibs and

[2] The Agricultural Marketing Service, formerly part of the Bureau of Agricultural Economics, assisted in grading each year.

when multiplied by 4 represents the theoretical additive genetic portion of the total variance or heritability. The results (table 3) indicate that variations in weaning score are slightly less heritable than variations in slaughter steer grade and that the latter is less heritable than variations in carcass grade. In weights at weaning and at slaughter time, it was previously reported (Knapp and Nordskog, 1946) that slaughter weight was much more

TABLE 2. INTRA-YEAR ANALYSES OF COVARIANCE (ADJUSTED MEAN SQUARES ONLY) OF SCORES, GRADES, CARCASS YIELD, AND AREA OF EYE MUSCLE

Source of variance	Degrees of freedom	Mean squares					Theoretical composition of mean squares
		Weaning score	Slaughter grade	Carcass grade	Carcass yield	Area of muscle	
Between sire groups	19	45.0*	9.63*	14.9*	117	2.22*	$A+kB^1$
Within sire groups	153	20.7	3.95	4.9	114	0.85	A

[1] k is equal to the average number of progeny per sire group or 7.696
* P is less than .01.

heritable than weaning weight. Differences in heritability of weaning score and slaughter steer grade are not large and thus it would appear that heritable differences can be recognized in conformation at much earlier ages than can weight. Dressing percentage indicates very low heritability but variations in area of eye muscle were approximately 69 percent heritable.

The estimation of heritability by sire:progeny regression as used by Knapp and Nordskog (1946) for the measures of growth is adaptable to but one of the measures of quality, namely, score at weaning. The following equation was used to estimate heritability from the sire:progeny regression:

$$h = 2b_{o:s}\sqrt{\frac{T_s}{T_o}}$$

where $b_{o:s}$ is the regression coefficient of offspring average on sire, T_s is the actual total variance of the entire unselected group of sires, and T_o is the total variance of the individual steer offspring. Since a correlation of 0.68 was observed between weaning weight and score at weaning, the scores were corrected for both the sires and the offspring to a standard weight. The adjusted scores of the sires and offspring were then analyzed. The regression coefficient was found to be $-0.07 \pm .10$. A low negative regression was obtained and thus the best estimate of heritability from a negative regression would be zero. The regression coefficient was not significantly

TABLE 3. THEORETICAL VALUES OF VARIANCES AND HERITABILITY OF WEANING SCORES, SLAUGHTER GRADES, CARCASS GRADES, CARCASS YIELD, AND AREA OF EYE MUSCLE

Index of merit	A	B	A+B	Heritability 100 h	Lower fiducial limits[1]
Weaning score	20.74	3.17	23.91	53	3
Slaughter steer grade	3.95	0.74	4.69	63	9
Carcass grade	4.88	1.30	6.18	84	23
Area of eye muscle	.8543	.1774	1.0317	69	13
Carcass yield	113.81	0.41	114.22	1	—

[1] The significance of a mean square is obtained by dividing it by its appropriate error mean square. The resulting ratio is F. In terms of mean square components $F = \frac{(A + kB)}{A}$ which is equal to $(1 + K\frac{B}{A})$. B is therefore equal to $\frac{(F-1)A}{K}$ for an n and n' degrees of freedom. Since H is equal to $\frac{4B}{A+B}$ and substituting for B in the equation, the following equation expresses the sampling error of $H = O$, $E_h = \frac{4(F-1)}{K+F-1}$. In order to calculate chance deviations from true heritability (H is greater than zero) it is necessary to employ Fisher's Z for which the upper and lower limits may be obtained for a given level of probability. By converting the fiducial limits of Z in terms of F and substituting into the formula: $\frac{4(F-1)}{K+F-1}$ we obtain the fiducial limits of H. (See Knapp and Nordskog (1946.)

different from zero. In view of the fact that only 20 degrees of freedom were involved this low heritability may be due to sampling errors.

The results from paternal half-sib analysis are in agreement with those observed on similar characters in swine and sheep. Lush (1936) shows a heritability of 47 percent for thickness of backfat in swine, 46 percent for thickness of belly, and 54 percent for body length. Hetzer, Dickerson and Zeller (1944) estimated that 38 percent of the differences in body scores between pigs within strains and season were heritable and that 92 percent of the variations between different strains within season were heritable. Terrill and Hazel (1943) estimated that only 12 percent of the variation in body score in sheep were due to heritable differences.

As a general conclusion, quality measures seem less heritable than the production measures previously reported. This may be due to lack of more concrete measures of quality of product or to a reduction in variability of these qualities through selection in the past by beef cattle breeders. However, there still appears ample opportunity for further selection. Dressing percentage seems more controlled by environmental influences and though the purebred breeders refer to breeding for high dressing percentage there

seems to be little chance to make marked improvement through selection alone. Dressing percentage is apparently a matter of degrees of finish and only changes in fattening at the same weight would materially affect the dressing percent.

The results of this study are more in line with the results of similar studies on other classes of livestock than was observed by the writers in rate and efficiency of gain. However, this study is subject to relatively large errors due to the restricted nature of the data. If it is later found, through subsequent analyses of other data, that these estimates are essentially correct, the breeder of beef cattle may simplify his procedure of selection for most of these traits. In fact it appears that the influence of heredity on live animal scores and grades may be high enough to make selection based on individual performance effective without the use of the progeny test. For the carcass characteristics, progeny tests are the only means of selection available until it can be proven that these characters are closely associated with some live animal traits.

Summary

A study was made of the record of 177 steer calves from 23 sires at the U. S. Range Livestock Experiment Station to estimate the relative effect of heredity on score at weaning, slaughter grade, carcass grade, dressing percentage, and area of cross-section of eye muscle. The animals used were the same as those used for a previous study on weight and gains. Heritability was estimated by the use of the paternal half-sib correlation from analysis of variance and in addition from the sire:offspring regression in the case of score at weaning.

Heritabilities obtained by intra-sire correlations for the characteristics studied were: Score at weaning 53 percent, slaughter grade 63 percent, carcass grade 84 percent, dressing percentage 1 percent, and area of eye muscle 69 percent. The regression of score at weaning of progeny on sire was negative ($b = -0.07$) and was not significantly different from zero. Heritability was therefore, not significant.

It was concluded that though there seems to be less heritability in the measures of quality of product than in the measures of growth, there is ample opportunity for selection for these characteristics.

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THE EFFECT OF FINENESS OF GRINDING ON THE UTILIZATION OF OATS BY MARKET HOGS

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THE inability of swine as a species to utilize large quantities of fibrous material in the diet has led to much controversy over the relative merits of certain feeds. Oats in particular has come in for much discussion in this connection. This material contains on the average about 30 percent of hulls which are apparently quite highly lignified (Bryner, *et al.*, 1936). Digestion studies (Bohstedt and Fargo, 1933; Crampton and Maynard, 1938; Mangold, 1934; Mitchell and Hamilton, 1933; Trautmann and Asher, 1942; Vestal, 1921; Watson, *et al.*, 1934) suggest that the hull of the oat adds little to the energy component of the pig diet.

It is reasonable to believe, however, that the fineness with which the oat hull is ground will determine to some extent the availability of any nutrients which it contains. The literature fails to reveal satisfactory information on this particular point. It seemed desirable, therefore, to obtain information concerning effects of fineness of grinding on the feeding value of oats in order to establish how best this feed might be used in swine rations.

Experimental Procedure

Yorkshire barrows, on attaining a liveweight of 50 pounds, were confined for 15 days in metabolism crates during which time data necessary for calculation of digestion coefficients and nitrogen balances were obtained. Following this initial digestion period the pigs were placed in individual feeding pens and continued for 60 days on the same diet, during which time feed consumption and growth were measured weekly. They were then returned to the metabolism crates for a second digestion and nitrogen balance trial.

Three different moduli of ground oats were involved and altogether three groups of three pigs each were used in the study.

The oats used was a good quality, grading No. 3 Canadian Western. Different samples were ground to three moduli of fineness, designated as coarse, medium and fine. The sieve classification of the three grindings shown in figure 1 is descriptive of the moduli actually employed.

There was a greater difference in appearance between medium and fine than between medium and coarse grinds. The important factor, however, is

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that the identity of the hulls, as such, had been destroyed in the fine grind.

The oat material constituted 85 percent of the total ration fed the pigs. The balance was a mixed protein-mineral supplement containing meat meal, linseed oilmeal, bone char, limestone and salt. Fish-liver oil was given daily to the young pigs to provide vitamins A and D.

During the two digestion periods the animals were fed at constant levels

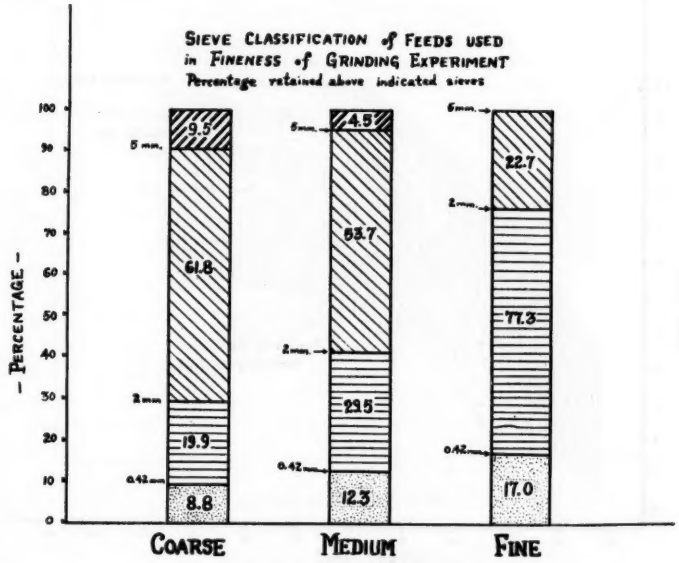

Figure 1. Sieve classification of feeds.

approaching full-feed intake. During the interim period animals were given all they would consume, and feeding was done three times per day.

Feed and faeces samples, taken during the digestion period, were dried at 105° C. and composited for the necessary chemical determinations. The urine was collected in glass containers under sulphuric acid, 1/100 aliquots being saved twice daily.

Results

Growth and Feed Consumption Records

The effects of the grinds were reflected almost immediately pigs were placed on full feed for the growth test. The average daily gains of the pigs at successive stages of their liveweight development have been plotted in

figure 2. These curves were superimposed on the band defining average growth curves ± 1 standard deviation (Ashton and Crampton, 1943).

It is very evident from this chart that the fine grinding permitted considerably more rapid rate of gain than was the case with either the medium or coarse grindings. It is also interesting that until the pigs weighed 100

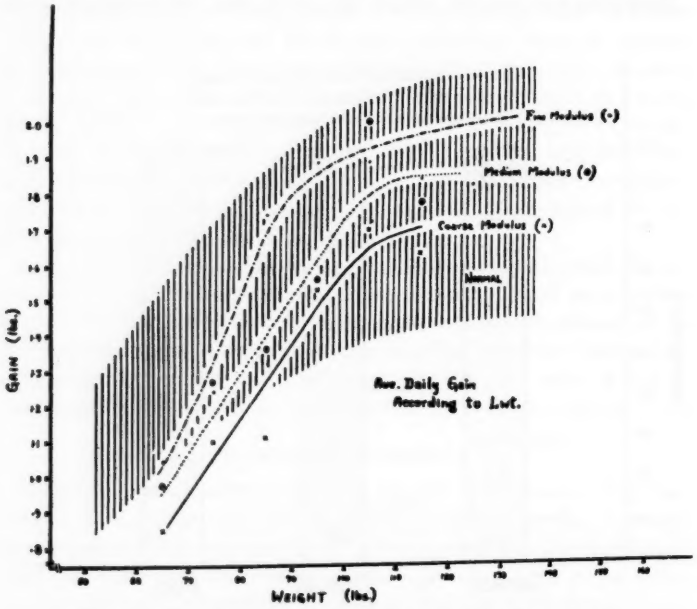

Figure 2. Curves showing daily gains according to liveweight.

pounds their gains tended to be below average but that from then on they appeared able to make gains closely approximating normal liveweight increases.

This is undoubtedly correlated with the observation that up until the pigs weighed nearly 100 pounds they consistently refused appreciable portions of the coarser grinds.

Differences in growth rates, however, were probably not due primarily to differences in amounts of feed consumed.[2] If feed refusals during the growth test corresponded to those measured during the digestion periods,

[2] The feed consumption curves in figure 3 represent the total feed offered to the pigs with no deductions for feed refused or wasted.

then the actual consumptions would not be significantly different among the three moduli.

In table 1 the data for growth and feed consumption are shown. Of particular interest is the finding that the young pigs will consume all of the finely ground oats but will leave increasingly larger proportions as the grind is coarsened. Heavy pigs, however, readily consumed practically all of the oats regardless of fineness of grinding.

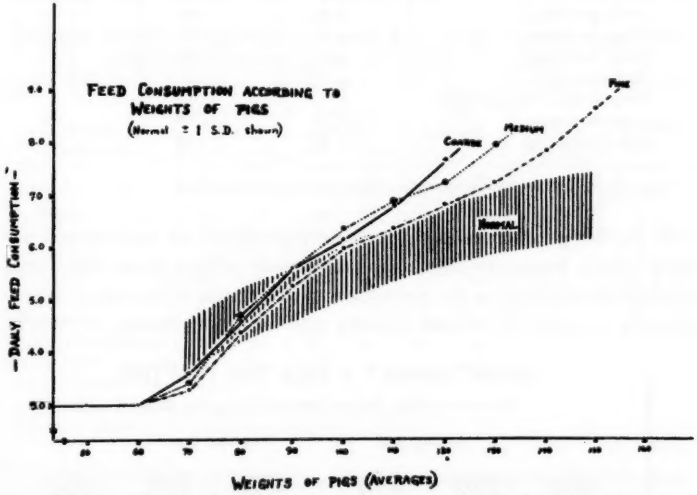

Figure 3. Curves showing feed consumption according to liveweight.

Digestibility Studies

The general picture of the digestibility of these three grindings of oats is shown in figure 4. The data for the fattening pigs show that there is no appreciable difference in the utilization of the three grinds of oats for pigs weighing about 150 pounds.

The figures for the 50 pound growing pigs show quite a different picture. When feed refusals are counted as faeces, it appears that the finely ground ration was more highly digested than were those in which the identity of the hull was not destroyed by fine grinding. There did not appear to be any significant difference between the medium and coarse grinds in this connection.

Of special significance is the relationship between the dry matter recovered in the faeces and that recovered as refused feed. It will be noted that

TABLE 1. GROWTH AND FEED CONSUMPTION

Items compared	Fineness of grinding		
	Coarse modulus	Medium modulus	Fine modulus
Initial weight (lbs.)	53.7	51.3	52.7
Final weight (lbs.)	121.0	132.0	155.0
Gain (lbs.)	67.3	80.7	102.3
Daily gain (avg.)	1.05	1.26	1.60
Total feed offered	313.6	330.2	362.9
Daily feed (avg.)	4.9	5.2	5.7
Feed/gain ratio	4.6:1	4.1:1	3.6:1
Percent feed D.M. refused*			
Growing pigs	17.27	12.78	0
Fattening pigs	1.97	.18	0

* Figures obtained from the digestion trials at the beginning and end of the feeding trials.

with the fine grind there was no refused feed. With the medium and the coarse grinds where considerable portions were refused there was a corresponding reduction in the proportion of dry matter recovered as faeces. Actually a total of the refused feed dry matter plus dry matter in faeces in

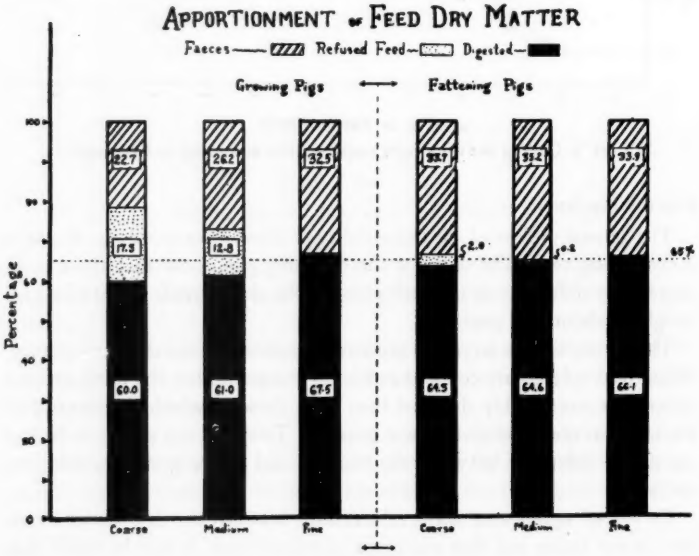

Figure 4. Apportionment of the dry matter offered.

both the medium grind and in the coarse grind amounts to only a little more than the total faeces dry matter found where all of the oat hulls were consumed. Thus it is evident that though in the fine grinding all of the hulls were consumed they were largely recovered in the faeces.

If in the case of the growing pigs the digestibility is determined only on the feed consumed, (i.e. deducting the amounts of refused material from total offered), there would be an apparent increase in digestibility with increasing coarseness of the grind. This obviously is due to the fact that the

TABLE 2. DIGESTION COEFFICIENTS OF THE MIXED RATIONS ON THE BASIS OF THE AMOUNTS ACTUALLY CONSUMED

Ration constituent	Coarse modulus		Medium modulus		Fine modulus		Coeff. of variation	Necessary difference†
	I*	II*	I	II	I	II		
Dry matter	73	66	70	65	68	66	1.8	2.7
Crude protein	86	83	85	82	81	80	0.9	1.7
Ether extract	83	81	82	80	76	74	3.6	6.5
Crude fibre	23	7	21	14	21	15	30.0	11.4
N.-free extract	79	75	77	73	77	76	2.6	4.5
Cellulose	24	18	23	18	26	22	9.0	4.4
Soluble carbohydrates	85	80	84	80	81	81	1.6	2.9
Lignin (72%)	42	34	36	37	40	43	5.0	4.3

* I and II represent the trials on growing and fattening pigs respectively.
† Necessary difference for significance taken at odds of 19:1 or P = .05.

material refused by the pigs is largely the indigestible material. If the increase in percentage digestibility of the medium modulus over the coarse modulus is credited to the difference in refused feed then the refused feed had a potential digestibility of 22 percent. Similarly, between medium and fine moduli the coefficient of digestibility for the refused feed would be calculated at about 51 percent. Thus it is probable that the finer grinding affects the digestibility of the fibrous material to some extent. A similar trend appears to exist with the older pigs where feed refusals were practically negligible.

Preliminary to a final evaluation of the rations as affected by modulus of grinding a study was made of the digestibilities of the separate feed fractions. Nutrient components of the refused feed were deducted from the total nutrients offered to obtain actual intakes. Consequently the digestion coefficients were based only on nutrients eaten. These data are shown in table 2.

The errors and implications of treating feed refusals in this way for practical evaluation of feeds are quite obvious, but this method nevertheless

allows for a more critical analysis of the effects of modulus of grinding on the individual fractions than where feed offered is the basis of the digestibility coefficient.

The effect of modulus of grinding on dry matter and organic matter digestibility reflects the unacceptability of the coarser material comprising mostly unmodified hulls. The tendency of the young pigs to sort out most of the hulls in the two coarser grinds resulted in significantly higher digestion coefficients for the consumed portion with the young pigs than were obtained from the older pigs on the same feeds. When feed refusals became smaller, modulus differences decreased. Consequently no differences in digestibility of dry matter or organic matter were obtained on the heavier pigs.

The effect of modulus on the digestibility of crude protein and of soluble protein was practically the same as that for dry matter.

The digestibility of the nitrogen-free extract was unaffected by modulus. This fraction appeared to be equally available (or unavailable) in the hulls regardless of grinding. The coefficient of variability in the digestibility of crude fibre was exceedingly high, indeed nearly 30 percent. It was not possible to detect any modulus differences in this fraction.

However, when the digestibility of cellulose is examined it may be noted that the coefficient of variability between pigs was only 9 percent. On the coarse and medium moduli cellulose was better digested where less of it was consumed. No age differences occurred on the fine modulus but it appears that fine grinding increases the digestibility of the cellulose.

As with cellulose, the higher digestion coefficients and the reduced variability of the soluble carbohydrate fraction reflects the advantage of the separation of the lignin component. The digestibility of soluble carbohydrates is about the same in all tests except where high feed refusals occur.

The uncertainty of the lignin determination makes conclusions concerning the utilization of this fraction by the pig unreliable.

In summarizing the findings on digestibility, the chief effect of modulus was to change the physical nature of the products so as to influence acceptability of the ration. The refusing of fibrous portions which were relatively indigestible effected increases in the digestibility of the remaining energy yielding fractions. Cellulose digestibility may also have been somewhat increased by fine grinding.

Estimation of Total Digestible Nutrients

From the standpoint of practical feed evaluation, portions of the ration which have been sorted out and left uneaten have served no useful purpose in the diet and may, therefore, be considered totally indigestible and the

digestibility coefficients may be obtained by adding the refused feed to the faeces for the calculations of total digestible nutrients.

The significance of these two methods of calculating digestibility coefficients and their influence on total digestible nutrients and digestible crude protein is shown in table 3.

TABLE 3. COMPARISON OF METHODS FOR CALCULATING TOTAL DIGESTIBLE NUTRIENTS AND DIGESTIBLE CRUDE PROTEIN VALUES

Feed fraction	Percent in complete ration (D.M.)	Coarse				Medium				Fine	
		I*		II*		I		II		I	II
		Offered	Consumed	Offered	Consumed	Offered	Consumed	Offered	Consumed	Offered	Offered
Crude protein	16.6	76	86	83	83	75	85	81	82	81	80
Ether extract	3.6	73	83	81	81	75	82	80	80	70	74
Crude fibre	11.1	17	23	7	7	18	21	14	14	21	15
N.-free extract	60.6	69	79	75	75	70	77	69	73	77	76
Soluble carbohydrates	57.0	74	85	80	80	76	84	80	80	81	81
Cellulose	10.5	18	24	18	18	19	23	18	18	26	22
T.D.N.[1]		62	72	66	67	63	70	63	66	68	67
T.D.N.[2]		63	71	68	69	65	71	67	68	69	68
D.C.P.		13	14	14	14	13	14	14	14	14	14
Mean difference in digestibility coefficients		9.0		0.3		6.0		0.9		0	

*I Refers to the digestion trials on 50 lb. pigs, II refers to digestion trials on the same pigs 60 days later. The columns 'Offered' and 'Consumed' refer to the method of treating refused feed, the latter bases digestion coefficients on the amount of substance consumed.

[1] Calculated from the proximate principles.

[2] Calculated from Crampton-Whiting carbohydrate breakdown, i.e., soluble carbohydrates and cellulose instead of crude fibre and nitrogen-free extract.

In general it is seen that for young pigs the total digestible nutrients consumed increase by about 3 pounds in every 100 pounds of feed offered between moduli, with the finest grinding giving the highest value. In other words, it appears reasonable to conclude that fine grinding provides about 6 pounds additional total digestible nutrients per 100 pounds of feed, over what is available to the pig in coarse grinding, and that most of this difference may be attributed to the non-fibrous carbohydrate portions lost in the refused feed.

Though this difference, in available total digestible nutrients, doubtless has some effect on the gains made per unit of feed consumed it does not seem, in this test, that the entire difference in growth rates can be accounted for by the increase of total digestible nutrients resulting from fine grinding. Table 4 shows the relationship of the gains made during the growth period

to the total digestible nutrients consumed according to the three degrees of grinding.

It will be noted, in every case, that less total digestible nutrients are required per unit of gain as the modulus of grinding becomes finer.

TABLE 4. RELATIONSHIP OF GAINS TO TOTAL DIGESTIBLE NUTRIENTS CONSUMED

Modulus	Growth period (days)	Gain (lbs.)	T.D.N. (lbs.)	T.D.N. / Gain
Coarse	7–35	23	66.4	2.87
	35–63	39	123.0	3.15
Medium	7–35	26	70.0	2.69
	35–63	46	131.6	2.86
Fine	7–35	38	86.4	2.27
	35–63	55	141.8	2.58

A more critical study of this possibility is presented in table 5. It is evident that there was less of the digested nitrogen being excreted as the modulus became finer, but since the amounts of protein retained per unit gain were probably not different between moduli, it appears that the amounts of nitrogen excreted in the urine were a consequence of the differing rates of gain. Less of the digested nitrogen from the coarser moduli was being utilized for growth.

Reference to the soluble carbohydrate:gain ratios reveals superiority of the finer moduli. This is in part due to the lower feed intakes on coarse

TABLE 5. EFFECT OF MODULUS OF GRINDING ON UTILIZATION OF PROTEIN AND SOLUBLE CARBOHYDRATE

Modulus	Feed consumption	56-Day gain	Soluble carbohydrates digested per lb. of gain	Protein digested per lb. of gain	Protein retained per lb. of gain	Nitrogen loss contained in urine[1]
	lbs.	lbs.	lbs.	lbs.	lbs.	*percent*
Coarse	288	62	2.00	.52	.20	77
Medium	304	72	1.82	.53	.19	76
Fine	336	93	1.55	.48	.17	71

[1] This represents that fraction of the total faecal and urinary nitrogen loss which was excreted via the urine. Similar amounts of protein were digested but different proportions were actually utilized in the body. Necessary difference for significance between moduli = 1.3 at $P = .05$.

grinds, with consequent reduction in the above-maintenance fraction available for growth. However, even these animals were gaining over one pound per day.

Since the chief differences between the feed materials actually eaten of the coarse vs. fine grinds were the greater amounts of hull consumed in the latter case, it follows that these hulls may have contributed something, chemical or physical, which facilitated the metabolism of dietary nutrients, particularly the carbohydrates.

Conclusions

1. When pigs of 50 pounds initial weight were fed on coarse, medium, or finely ground oats, adequately supplemented by proteins and minerals, significantly faster gains were obtained as the modulus became finer. Pigs fed coarse, medium, and fine modulus reached 121, 132, and 155 pounds liveweight, respectively in 60 days of feeding.

2. Feed consumption over the 60-day growth period increased as the modulus became finer but this was due almost entirely to the increased size of pig because of faster growth rates. Pigs of equal size ate approximately equal amounts of feed daily.

3. Fibrous portions made up largely of hulls were decidedly unpalatable to the younger pigs, and unless they were finely ground, they were sorted out and refused.

4. Grinding oats to various degrees of fineness did not affect the extent to which the older pigs digested the dry matter. When the young pigs were unable to separate the hulls, because of fine grinding, no age differences were noted in dry matter digestibility.

5. The importance of considering feed refusals in the evaluation of a ration has been demonstrated. If digestibility coefficients are calculated on the basis of feed actually consumed the total digestible nutrient values appear to increase with coarser grinding. When refused feed was considered as faeces, there was an increase of about 3% in the digestibility between each modulus of grinding with the coarse grind the least digestible. Most of this increase in digestibility with finer grinding can be accounted for by the greater digestibility of the carbohydrate fractions.

6. The possibility of a factor, or factors, contained in oat hulls affecting nutrient utilization has been discussed in relation to the differences in the proportions of total digestible nutrients required per unit of gain.

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THE VALUE OF SHARK MEAL IN SWINE RATIONS[1]

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SHARK meal is a by-product of the shark fishing industry and is a relatively new animal feedstuff to come on the market. The use of shark liver oil as a source of vitamin A has resulted in a great increase in shark fishing which has been reflected in the production of shark meal. The total production of shark meal in the United States has increased from 527 tons in 1940 to 614 tons in 1942 (U. S. Dept. of Interior, 1940, 1942). Shark meal production was begun in Florida in 1941 to make use of the shark carcasses which remain after the hides, liver, dorsal fins, and in some cases, teeth and jaws have been removed. In the production of shark meal in Florida, the carcass is cut up into pieces approximating 8 inches in diameter, put into an open tank cooker and cooked by steam at a temperature approximately 190° F. The cooked pieces are then conveyed by a screw conveyor, which allows drainage, to a hammer mill and ground to pass through a $\frac{1}{4}$ inch screen. The ground shark is then conveyed directly to a rotary drum drier which is so regulated that the material is scraped off in flakes before the moisture has been reduced to the desired level. Heat in the material completes the drying process and the flakes are ground into a meal which goes directly into sacks. The shark meal is high in protein, being exceeded only by the dried blood products. The crude protein analyses of samples received have ranged from 63 percent to 88 percent. The average crude protein (N×6.25) of 19 samples was 78.07 percent. Shark meal is also a good source of calcium and phosphorus, averaging 3.48 percent and 1.92 percent respectively in the 19 samples analyzed.

A protein supplement of animal origin in swine rations generally is recommended. In this investigation the suitability of shark meal as a protein supplement was studied by comparing its feeding value with that of roller process powdered dried skimmilk.

It was realized that the limiting factor in the total use of the nitrogen of shark meal by swine probably would be the non-protein-nitrogen fraction which in the shark meal used averaged 1.75 percent urea and 0.49 percent non-protein nitrogen not urea. In this experiment the shark meal was evaluated on the basis of its total nitrogen content as crude protein. Because of

[1] The experimental data of this paper were taken from the thesis submitted by S. P. Marshall to the University of Minnesota as a partial fulfillment of the Ph.D. degree requirements. Approved for publication by the Director of the Florida Agricultural Experiment Station. The authors gratefully acknowledge the assistance of Dr. R. S. Glasscock in grading the carcasses and of Mr. J. E. Pace in the selection and care of the pigs.

the difference of opinion as to the requirements for digestible crude protein and of total crude protein by growing swine (Carroll and Burroughs, 1939; Ellis and Zeller, 1939; Evvard, 1929; Mumford, 1935 and 1936; Ellis and Hankins, 1935; Morrison, 1936), it was decided to use a level below that required for maximum nitrogen storage by the pigs at the different weights. Thus, any difference between the nutritive value of the rations containing shark meal and that of rations containing the dried skimmilk, used as a check, would be accentuated. Because of the recognized change in protein requirements with increasing weight, the rations of the experimental pigs were changed when the pigs reached weights of 75, 100 and 150 pounds. The pigs were kept on the experiment a total of 16 weeks.

Experimental Procedure

Two litters of three-quarter sib Poland China pigs farrowed on successive days were available as experimental subjects. At 7 weeks the male pigs were castrated and at 8 weeks of age, all pigs were inoculated against hog cholera. The pigs were weighed and weaned at 9 weeks of age, and on the

TABLE 1. COMPOSITION OF MINERAL MIXTURE IN SWINE RATION

Component	Percent
Defluorinated superphosphate	50.0
Sodium chloride—feedstuff grade (NaCl)	33.4
Potassium chloride Technical (KCl)	10.0
Ferric chloride C.P. ($FeCl_3 \cdot 6H_2O$)	3.0
Magnesium oxide U.S.P. light powder (MgO)	2.6
Manganous sulphate C.P. ($MnSO_4 \cdot 4H_2O$)	0.5
Copper sulphate –$CuSO_4 \cdot 5H_2O$)	0.2
Cobalt sulphate—feedstuff grade ($CoSO_4 \cdot 7H_2O$)	0.1
Zinc oxide C.P. (ZnO)	0.1
Potassium iodide U.S.P. (KI)	0.1

basis of weight and general condition at the time of weaning, two pairs of males and three pairs of females were selected, numbered 1 through 10 and placed in the experimental pens. At 9 weeks of age the pigs were given the rations they were to receive during the experiment and at 10 weeks of age, the pigs were weighed and placed on experiment. The basal ration was composed of yellow corn, ground through a $\frac{1}{4}$ inch screen with a hammer mill, and a mineral mixture equivalent to 4 percent of the total rations. The components of the mineral mixture used in the swine rations are listed in table 1.

At this level of feeding, the mineral mixture supplied the requirements

of growing pigs for phosphorus as established by Aubel, Hughes, and Lienhardt (1936), and for calcium as recommended by Aubel, Hughes and Peterson (1939). The other elements were present in quantities similar to those used in purified diets for swine by Hughes and Squibb (1942). To the basal ration, shark meal and powdered skimmilk were added as shown in table 2.

TABLE 2. INGREDIENTS OF SWINE RATIONS

Pig weight	Ration no.	Ground yellow corn	Mineral mixture	Corn starch	Shark meal	Powdered skimmilk
		percent	*percent*	*percent*	*percent*	*percent*
to 75 lbs.	3	61.25	4.00	20.77	13.98	
	4	62.60	4.00			33.40
76–100	3	69.00	4.00	16.24	10.76	
	4	70.30	4.00			25.70
101–150	3	75.40	4.00	12.31	8.29	
	4	76.20	4.00			19.80
151–225	3	81.20	4.00	8.90	5.90	
	4	81.90	4.00			14.10

Shark meal was included in the rations at levels ranging from 13.98 percent to 5.9 percent to meet the minimum protein requirements and to provide a test of the availability of the non-protein nitrogen present in the shark meal. Corn starch was used to equalize the rations.

These rations were designed to supply protein at a level of 17 percent for pigs weighing up to 75 pounds, 15 percent from 76 to 100 pounds, 13.5 percent from 101 to 150 pounds in weight, and 12 percent from 151 pounds until the swine were slaughtered. The pigs were given 21,000 international units of vitamin A per 100 pounds live weight per week in the form of shark liver oil. The allotment of shark liver oil was mixed in the morning feed once weekly. The week's supply of water-soluble vitamins as listed in table 3, was placed in aqueous solution and was mixed with the morning rations the day following the shark liver oil.

The pigs were kept on concrete in individual pens which were approximately two-thirds covered by a frame and roofing paper shelter. The pens were cleaned and washed down with a hose on alternate days. The pigs were fed twice a day and water was kept before them at all times. The consumption of feed by the pairs was equalized according to the paired feeding technique described by Mitchell and Carman (1926). Each pig was given 8 grams of phenothiazine at 9 weeks of age, and 17 grams on the 78th day of the experiment. Live weights of the pigs were taken before the morning feed on the initial day of the experiment and at weekly intervals thereafter. The final body weight was calculated by averaging the weights be-

fore, on, and after the last regular weigh day. At the termination of the experiment the pigs were slaughtered at a packing house and post-mortem observations were made on the internal organs by a competent veterinarian. The carcasses, dressed "packer style," were chilled for 24 hours, weighed and graded. A sample from the chilled carcass of pig No. 3 and one from

TABLE 3. WEEKLY ALLOWANCE OF WATER-SOLUBLE VITAMINS

Vitamin	Allowance, Mgs./100 lbs. live weight
Thiamin hydrochloride	7
Riboflavin	21
Calcium pantothenate	84
Nicotinic acid	70
Pyridoxine hydrochloride	35
Choline hydrochloride	70

pig No. 4 were used in a cooking test. The loins were roasted in separate ovens at a temperature of 350° F. A slice from each loin was served warm to 20 faculty members who checked the lean and the fat for flavor.

Results

The live weights of the pigs at the beginning of the experiment ranged from 40.5 to 51.0 pounds. Those placed on the shark meal rations averaged 45.5 pounds and those fed the powdered skimmilk rations, 45.4 pounds. The difference in weight between the individuals within the pairs ranged from 0.1 to 3.5 pounds. At the end of the 16 weeks' feeding period, the swine receiving shark meal averaged 192.5 pounds, a gain of 147.0 pounds, and those receiving powdered skimmilk averaged 186.9 pounds, a gain of 141.5 pounds. With the exception of pig No. 9, those fed shark meal rations made greater gains than pair mates receiving the powdered skimmilk rations. The barrows (pigs Nos. 1, 2, 3, and 4) gained more rapidly than did the gilts. Initial live weights, weights at 8 and 16 weeks, and total gains are shown in table 4. Figure 1 shows graphically a comparison of the average gains of the pigs on each of the rations and the normal growth curve of Ittner and Hughes (1938).

The composition of the rations was calculated from the analyses of the ingredients. The shark meal and powdered skimmilk rations containing the same nitrogen content were quite similar in composition. The successive decreases in the crude protein level from 17 to 12 percent were accom-

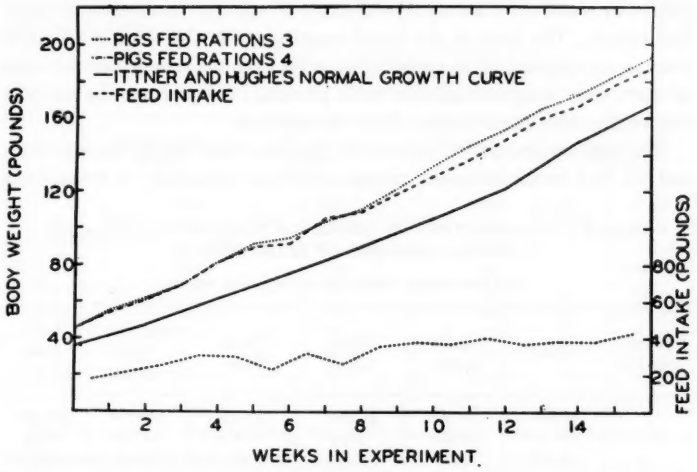

Figure 1. Average weekly feed consumption and a comparison of Ittner and Hughes' normal growth curve and the average gains of pigs fed each of the rations.

TABLE 4. LIVE WEIGHTS AND TOTAL GAINS OF SWINE

Ration 3 (containing shark meal)

Week of experiment	Identification of pigs					
	Pig. 1	Pig. 3	Pig. 5	Pig. 7	Pig. 9	Av.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Initial	43.0	49.5	49.5	45.0	40.5	45.5
8	109.0	122.5	113.5	104.5	100.5	110.0
16	194.5	210.8	191.8	184.5	181.2	192.5
Total gain	151.5	161.3	142.3	139.5	140.7	147.0

Ration 4 (containing powdered skimmilk)

Week	Pig. 2	Pig. 4	Pig. 6	Pig. 8	Pig. 10	Av.
Initial	45.5	48.0	51.0	41.5	41.0	45.4
8	116.5	113.5	107.0	98.0	107.0	108.4
16	196.5	199.2	185.5	169.8	183.5	186.9
Total gain	151.0	151.2	134.5	128.3	142.5	141.5

panied by slight reductions in the mineral content and increases in nitrogen-free extract. The total of the listed constituents in the shark meal ration exceeds 100 percent. This apparently results from the non-protein nitrogen of shark meal being calculated as crude protein. Table 5 shows the composition of the rations as calculated from the analyses.

The pigs consumed from 15.4 to 18.7 pounds of feed during the first week, and the feed intake increased, though somewhat irregularly at times, to an

TABLE 5. COMPOSITION OF SWINE RATIONS AS CALCULATED FROM ANALYSES OF INGREDIENTS

Fed from initial weight to 75 pounds live weight

Ration number	Water	Crude protein	Ether extract	Crude fiber	Nitrogen-free extract	Ash
	percent	*percent*	*percent*	*percent*	*percent*	*percent*
3	12.06	17.00	3.33	1.11	61.10	6.39
4	10.88	17.00	3.32	1.13	60.36	7.31
Fed from 76 to 100 pounds live weight						
3	12.16	15.00	3.62	1.21	62.68	6.09
4	11.25	15.00	3.62	1.24	62.09	6.80
Fed from 101 to 150 pounds live weight						
3	12.24	13.50	3.85	1.30	63.81	5.87
4	11.54	13.50	3.85	1.31	63.38	6.42
Fed from 151 to 225 pounds live weight						
3	12.31	12.00	4.07	1.37	64.91	5.66
4	11.82	12.00	4.08	1.38	64.67	6.05

average of 42.7 pounds during the final week. The number of days that each pair of pigs was fed on the various protein levels and the total amounts of feed consumed by the individuals at each protein level are shown in table 6. The average feed consumption is also shown in figure 1.

A week prior to the initiation of the experiment, phenothiazine was administered to the animals and the elimination of round worms gave evidence that the pigs were infested with these parasites. This treatment did not eradicate these parasites from all of the pigs. Round worms were observed in the feces of pigs Nos. 2 and 7 prior to the worming treatment on the 78th day of the experiment and in the feces of pigs Nos. 2, 6, 7, and 8 following this treatment. Since only 1 to 8 worms were observed in the feces of these

infested pigs following this second worming, it appeared that the infestations were light.

TABLE 6. NUMBER OF DAYS AND TOTAL FEED INTAKE ON EACH LEVEL OF PROTEIN FEEDING

Pig no.	17% protein ration		15% protein ration		13.5% protein ration		12% protein ration	
	Days	Feed intake	Days	Feed intake	Days	Feed intake	Days	Feed intake
		lbs.		lbs.		lbs.		lbs.
1 or 2	24	74.5	20	79.5	35	179.2	33	198.0
3 or 4	23	74.4	15	72.5	36	163.8	38	225.9
5 or 6	23	74.1	22	87.4	34	157.5	33	181.7
7 or 8	25	80.2	22	81.5	37	182.2	28	151.2
9 or 10	26	78.6	21	78.1	37	180.0	28	144.4

At the time of slaughtering, the internal organs were inspected by a veterinarian who found no abnormalities.

There appeared to be no difference in the quality of the carcass of either pig of the pairs. On the basis of type and finish, all carcasses were graded "choice." The mean weight of the chilled carcasses, dressed "packer style," was 139.6 pounds for the pigs fed shark meal and 132.4 pounds for those fed rations containing powdered skimmilk. The dressing percentage of the pigs receiving shark meal was 72.5 percent and for those receiving powdered skimmilk, 70.8 percent.

Slices of roasted loins of pig No. 3 (fed shark meal) and pig No. 4 (fed powdered skimmilk) were served to 20 people. None of the judges detected any fishy or off flavors in the lean meat or the fat of the loin from either pig.

With the exception of pigs Nos. 1 and 9, the final weights of those that consumed shark meal rations were higher than the final weights of their pair mates receiving the powdered skimmilk rations, but on the basis of total gain, pig No. 10 was the only one fed the powdered skimmilk rations that exceeded the gain of its pair mate.

The average rate of gain of the pigs fed shark meal was slightly more rapid from the 8th to the 16th week on experiment than that of the pigs receiving powdered skimmilk rations, as shown in figure 1; however, the difference in the average gains was not significant as determined by the method of standard error, described by Snedecor (1937).

The appetites of the pigs were good through the first five weeks of experiment. However, as the pigs gained in condition and the summer heat became more intense, difficulty was experienced at times in keeping the pigs on full

feed. With the onset of cooler weather during the last weeks of the experiment, their appetites improved.

Summary

By use of the paired feeding method, shark meal has been compared with powdered skimmilk as a source of protein for growing and fattening swine.

The results indicate that on the basis of the crude protein content, shark meal is an acceptable source of protein for use in swine rations.

The ration containing shark meal as the principal source of protein produced growth in the pigs comparable to that seen in the pigs receiving roller process dried skimmilk as a source of protein. The average growth of the pigs in this experiment exceeded that shown by the Ittner and Hughes, (1938) standard growth curve for swine.

The shark meal did not produce any off or fishy flavor in the lean or fat of the animals, when their rations contained 5.9 to 13.98 percent of this new protein supplement.

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HERITABILITY OF LIVE ANIMAL SCORES, GRADES, AND CERTAIN CARCASS CHARACTERISTICS IN BEEF CATTLE

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THE writers (Knapp and Nordskog, 1946) recently presented a study of heritability of rate and efficiency of gain and weight at several ages in beef cattle. That study indicated that these measures of growth were in general highly heritable. The present paper deals with heritability estimates of scores at weaning, slaughter steer grades, carcass grades, dressing percentage and area of eye muscle. The two studies include the major performance characteristics in beef cattle that have been used in record of performance work.

Source of Data

All animals used in these studies were produced at the U. S. Range Livestock Experiment Station, Miles City, Montana, under cooperative projects between the Bureau of Animal Industry and the Montana Agricultural Experiment Station. Details of management of the breeding herds on

TABLE 1. AVERAGE SCORES, GRADES, DRESSING PERCENTAGES, AND AREAS OF EYE MUSCLE FOR EACH FEEDING YEAR

Year	No. of steers	Average score	Average slaughter grade	Average carcass grade	Average dressing percentage	Average area of eye muscle	Average final weight
	number	*percent*	*score*	*score*	*percent*	*inches*	*pounds*
1940–41	24	76.7	16.3	15.8	56.5	9.91	875
1941–42	62	76.5	15.7	16.2	58.4	12.36	919
1942–43	45	73.8	13.1	13.8	59.0	11.45	923
1943–44	46	72.8	15.0	15.2	58.0	9.42	851

the range, selecting, feeding, and handling of the steers are given in the previous paper (Knapp and Nordskog, 1946).

The 177 steer calves by 23 sires were scored on A.H. Form 522 at weaning time on about October 20 each year, by a committee of 3 men working independently. The average of the 3 scores was used as the score of each animal.

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sequent to weaning. Table 1 contains information on the vitamins fed these pigs during that period.

The basal ration used in this experiment consisted of sucrose 53.8, desic-

TABLE 1. THE EFFECT OF BIOTIN ON PIGS FED A RATION CONTAINING 30 PERCENT DESICCATED EGG WHITE

Items compared	Lot number	
	1	2
Ration fed	Basal	Basal+biotin*
Number of pigs	2**	2***
Initial age, weeks	22	22
Number of weeks on trial	6	6
Av. initial weight, lbs.	106.2	99
Av. daily gain, lbs.	0.52	0.94
Av. daily feed consumption, lbs.	3.22	3.21
Lbs. feed per lb. of gain	5.24	3.42

* 100 micrograms given each pig daily by intramuscular injection.

** These pigs received inositol in addition to the 6 B-complex vitamins (thiamin, riboflavin, niacin, pyridoxine, pantothenic acid and choline) for 16 weeks previous to being placed on this experiment.

*** These pigs received biotin in addition to the same 6 B-complex vitamins mentioned above, for 16 weeks previous to being placed on this experiment.

cated egg white[3] 30, lard 11, and mineral mix[4] 5.2 percent. With this basal ration, the following levels of vitamins were fed to the pigs:

Vitamin	Mg. fed daily per kg. live weight	Vitamin	Levels fed daily per pig
Thiamine	0.52	Vitamin A	5000 I.U.
Riboflavin	0.12	Vitamin D	500 I.U.
Niacin	1.20	Vitamin E	57 mg.
Pantothenic acid	.50	Vitamin K	2 mg.
Pyridoxine	.20		
Choline chloride	10.00		

The pigs were divided equally as to age and sex in two lots. The pigs in both lots were fed desiccated egg white, but in addition, those in lot 2 received biotin by intramuscular injection.

A modification of the "paired-feeding technique" (Mitchell and Beadles, 1930), was used in order to keep the feed intake of all pigs constant. Thus the feed intake of the pigs was limited to the amount consumed by the pig

[3] Foam-dried fermented egg white. The raw egg whites were fermented to remove the natural sugars and were then whipped into a foam which was placed on trays for drying. The temperature of the drying chamber was about 100–110° F. and the time for drying was about 30–45 minutes.

[4] Same as used by Wintrobe (1939).

with the smallest appetite—with the only variable being that biotin was given to the pigs in lot 2.

The pigs were fed in individual feeding stalls and were kept on raised floors in order to prevent coprophagy. The raised floors were washed twice daily. The individual feeding stalls and raised floors are described in a previous publication by Heinemann *et al.* (1945).

To prevent the development of rancidity and consequently the destruction of certain vitamins, the purified ration was kept in a refrigerator and not more than two or three days feed requirements were mixed at any one time.

All vitamins were kept in solution in a refrigerator. They were fed to the pigs every other day. The required amounts of the vitamins fed were measured in calibrated pipettes and placed on a small amount of the feed on the top of the ration at feeding time. In this manner, struggling with the animals was avoided and complete consumption of the vitamins was obtained.

Results and Discussion

Figures 1 and 2 show the syndrome obtained in the two pigs fed desiccated egg white in the ration. The syndrome began to appear about two and one-half weeks after the trial was initiated. At this time, both pigs in lot 1 began to show a loss of hair on the posterior part of the hams. The hair loss then proceeded over the back and sides of the body. The hair, over the surface of the body, was found to be very loose in these pigs. The alopecia and the appearance of an accompanying dermatosis occurred with about the same rapidity, and degree of severity. The cracks in the feet of the two pigs in lot 1, shown in figure 3, did not appear until the fifth week. The spasticity of the hind legs also appeared during the fifth week. The spasticity was not too severe. It might be expected that, had the experiment been continued for more than six weeks, the cracks in the feet and the spasticity observed might have become worse. The experiment was terminated at six weeks when the supply of egg white became exhausted.

The syndrome observed in the pigs in lot 1 was prevented in lot 2 by the daily intramuscular injection of 100 micrograms of crystalline biotin per pig. The biotin was dissolved and given in a 50 percent ethanol solution. This study showed that the deficiency symptoms exhibited by the pigs fed egg white (figures 1 and 2) were due to a biotin deficiency. It also showed that the avidin in egg white combined with or tied up the biotin in the ration and that synthesized by bacteria in the intestinal tract, so that it was made unavailable to the pig. This finding probably indicates that Willman *et al.* (1942) obtained good results with feeding incubated eggs to pigs because an insufficient amount of egg white was consumed to render all biotin un-

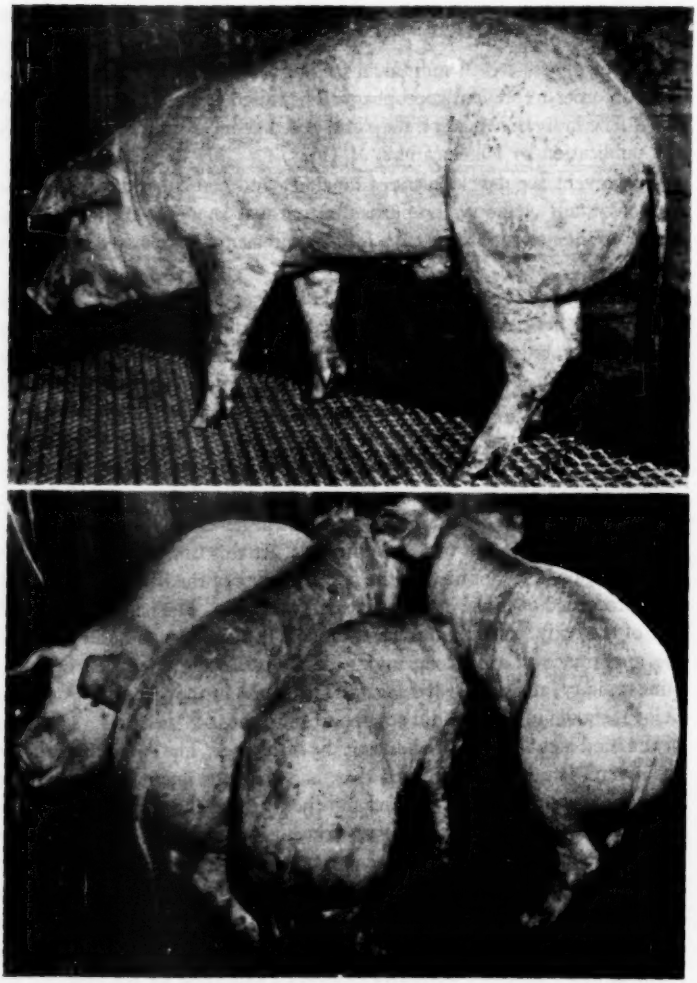

Figure 1 (top). Pig fed basal ration with desiccated egg white (lot 1). Note hair loss, spasticity of hind legs, cracks in feet, and dermatosis of the skin characterized by dryness, roughness, and a brownish exudate. This syndrome was prevented by biotin (see fig. 2).

Figure 2 (bottom). The two pigs in the middle were fed the basal ration with desiccated egg white (lot 1). The two pigs on the outside were fed the same ration plus biotin (lot 2). Note how biotin prevented the syndrome shown by the two pigs in the middle.

available, or that the temperature of the incubator modified the structure of avidin so that it no longer tied up biotin.

The data in table 1 show the difference in growth and efficiency of feed utilization by the pigs fed in both lots. The biotin-deficient-pigs in lot 1 required 50 percent more feed per pound of gain than the pigs fed biotin in lot 2. The addition of biotin to the basal ration in lot 2 resulted in an 80 per cent increase in daily gains.

Figure 3 (top). Note the cracks in the feet observed in the pigs in lot 1. This condition was prevented by biotin (see fig. 4).

Figure 4 (bottom). Pig from lot 2. Note that no cracks are present in the feet. Biotin prevented the cracks in feet shown in fig. 3.

Hegsted *et al.* (1940, 1942) reported that a deficiency of biotin with the chick resulted in hemorrhagic cracks and incrustations in the bottom of the feet. Biotin prevented a cracking of the feet in the pig in this experiment. This shows that the pig is somewhat similar to the chick in this respect.

A hair loss was first observed with the rat on a biotin deficiency by Boas (1927). She also reported a spasticity in the rat fed dried egg white. Similar results were obtained in this experiment, since a hair loss and a spasticity of the hind legs developed in the pigs fed desiccated egg white.

Summary and Conclusions

A biotin deficiency was produced in the pig by feeding 30 percent of desiccated egg white in the ration. The deficiency symptoms included alopecia, spasticity of the hind legs, cracks in the feet and a dermatosis of the skin characterized by dryness, roughness and a brownish exudate. This syndrome was prevented by intramuscular injection of 100 micrograms of biotin per pig per day.

A biotin deficiency in the pig resulted in 50 percent more feed being required per pound of gain and a decrease of 45 percent in rate of daily gain.

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TOLERANCE OF FARM ANIMALS TO FEED CONTAINING 2,4-DICHLOROPHENOXYACETIC ACID

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SUCCESS in controlling the growth of various annual and perennial weeds through the use of 2,4-dichlorophenoxyacetic acid (2,4-D) (Hamner and Tukey, 1944; Marth and Mitchell, 1944) has raised a question as to the toxicity of this substance to animals. Tests were undertaken to determine (a) the effect on sheep and cows maintained on pasturage that had been sprayed with a water mixture of the acid and (b) the effect of feeding a cow daily doses of 2,4-D. Tests were made also to determine whether 2,4-D or its salts was absorbed into the blood stream and excreted in the milk of a cow fed this acid.

Methods

A one-eighth acre pasture and a one-third acre pasture were selected for the grazing tests with sheep and dairy cattle. These pastures were sprayed with the weed killer on July 11, 1945. The spray used was prepared by dissolving one part purified 2,4-D (m.p. 140–141° C.) in 10 parts of melted Carbowax 1500 (Mitchell and Hamner, 1944), and mixing this solution with water to make a spray containing 0.15 percent of the acid and 1.5 percent of the Carbowax. The mixture was sprayed on the two pastures at the rate of 215 gallons per acre with a sprayer operating at 250 pounds pressure. At this rate of application about 86 percent more 2,4-D was applied per acre than is usually needed to kill such weeds as plantain, dandelion, or other common broad-leaved plants that grow in pastures and lawns or other grassy areas.

The day after the pastures were sprayed two sheep were turned onto the one-eighth acre pasture and two non-lactating cows were turned onto the one-third acre pasture. The sheep grazed on the sprayed pasture 12 days after which they were turned onto an untreated pasture. They were carefully observed each day for any abnormal condition.[4] They received no supplemental feed during the first part of the 12-day grazing period but as the pasture was grazed off supplementary feed was given.

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[4] Sheep and pasture used in this experiment were furnished by the Bureau of Animal Industry and observations regarding the behavior of the animals were made by N. R. Ellis.

The cows were fasted for 12 hours before they were turned onto the sprayed pasture. They grazed the pasture continuously for 48 days. During the first 14 days they received only the pasturage, while thereafter a small amount of hay was fed daily in addition. The cows were carefully observed each day for any abnormal condition that might occur and to determine if they were grazing the pasturage readily. At the end of the 48-day period the cows were slaughtered and post-mortem examinations made.

In order to determine the possible toxicity of larger amounts of 2,4-D and to learn if the substance is taken into the body and excreted in the milk, a lactating Holstein cow was fed 5.5 grams of the acid daily for 106 days, a total of 1.2 pounds, beginning on July 30, 1945. This amount is greatly in excess of the amount that would be consumed by a cow grazing on pasturage sprayed with 2,4-D at rates usually recommended for weed control. During this feeding period a record was kept of her physical condition, weight, feed consumption, and milk production. During the last 38 days her milk was fed to a calf, beginning at three days of age, to determine if the milk would produce any harmful effects. The milk and the blood serum of the cow and the blood serum of the calf were tested at intervals for the presence of 2,4-D. At the end of the 106-day period the cow was slaughtered and a post-mortem examination made. The liver, kidneys, and abdominal fat were tested for the presence of 2,4-D.

A plant test was used to determine the amount of 2,4-D or its salts present in the various samples of blood, milk, and body tissues. The stems of some kinds of succulent plants are extremely sensitive to surface applications of 2,4-D as well as the sodium salt of this acid and some of its other salts. The plants respond by greatly accelerated stem elongation (figure 1). Bean seedlings of the Black Valentine variety were first grown under greenhouse conditions. After the plants had reached a height of approximately 3.5 inches, a group was selected for size and uniformity, each of which had a first internode that did not vary in length more than 1 mm. from the average of the entire group. An attempt was made to select plants whose average length of internode was 13 mm. In some tests, however, it was necessary to use plants whose average length of internode was either 12 or 14 mm.

Treatments were made by applying 0.01 ml. of an aqueous mixture of the extract to be tested as a narrow band (approximately 2 mm.) extending around the internode midway between the first and second node. Ten replications of each treatment were used and these were arranged in the order of randomized blocks on a bench. The plants were illuminated by means of thirty-watt Daylite fluorescent tubes which supplied an intensity of approximately 800 foot-candles at the leaf surfaces. Air temperature

varied between 80° and 95° F. except in a few experiments in which the temperature reached 100° F. Measurements of internodal elongation were made at the time of treatment and at the end of approximately 24 hours following treatment.

In preliminary experiments it was found that blood serum from a cow that had not been fed 2,4-D did not stimulate internodal elongation of bean plants. The addition of a known amount of sodium salt of 2,4-D to a meas-

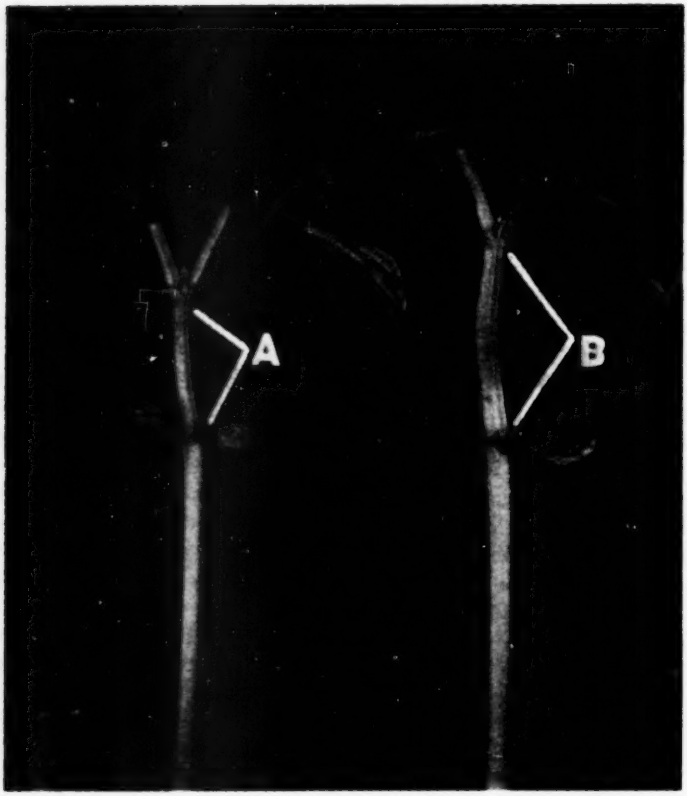

Figure 1. Bean seedlings used to measure growth-stimulating properties of blood serum, milk, and extracts of tissue from a cow fed 2,4-D. Length of first internode of bean seedling treated with serum from a cow not fed 2,4-D (A), compared with that of an internode treated with serum from a cow that consumed 5.5 grams of 2,4-D a day (B).

ured quantity of this serum, however, brought about slightly less internodal elongation than did an equal amount of the salt applied in water, indicating that the growth-stimulating effects of the salt were slightly depressed by some of the constituents of the serum. The activity of blood serum from the cow that had been fed 2,4-D was therefore estimated on the basis of the amount of pure sodium salt of 2,4-D required to bring about an equal plant response when dissolved in serum from a cow that had not been fed 2,4-D.

A 3-ml. portion of each serum sample was evaporated, the residue ground quantitatively to 60-mesh size, and extracted for 15 minutes with 5 ml. of hot distilled water. The mixture was filtered, the residue washed with hot water, and the filtrate evaporated just to dryness and the receptacle cooled. The residue was then washed into a centrifuge tube with 1 ml. of water and centrifuged for 5 minutes. The centrifugate was decanted and applied to the test plants as described, 0.01 ml. to each plant.

Milk from a cow that had not been fed 2,4-D did not stimulate internodal elongation of bean plants when applied as described, nor did milk depress the effectiveness of the sodium salt of 2,4-D in bringing about internodal elongation. It was therefore possible to test the milk from the cow that had been fed 2,4-D by comparing its activity with the amount of purified sodium salt of 2,4-D required to bring about an equal plant response when the salt was dissolved in water.

In testing for the presence of 2,4-D or derivatives of this compound in the tissues of the test animal, 60 grams of tissue was first finely ground in a meat grinder and then blended together with an equal weight of distilled water with a Waring blendor for 5 minutes. The solid particles were then centrifuged off and the liquid applied directly to the plants as previously described.

Results

Sheep grazing tests

During the 12 days that the sheep grazed the pasture treated with 2,4-D there was no indication that the grass was unpalatable. The sheep showed no ill effects from consuming the sprayed pasturage while they were on the treated pasture or at any time thereafter.

Cow grazing tests

The cows grazed the treated pasturage closely during the 48 days without any indication that it was unpalatable. They remained healthy and normal throughout the test period. Post-mortem examinations showed no abnormal conditions that could be attributed to the consumption of spray material on the pasturage.

Cow feeding tests

The live weight, milk production, and feed consumption records of the Holstein cow for 40 days before and for the 106 days during which she was fed 2,4-D are shown in table 1. It is apparent that the 2,4-D did not impair her appetite or cause her to lose weight. Milk production showed a fairly normal decline with advance in lactation period. The cow appeared healthy at all times and carried a calf throughout the 2,4-D feeding period.

TABLE 1. LIVE WEIGHT, AVERAGE DAILY MILK PRODUCTION, AND FEED CONSUMPTION OF A COW BY 10-DAY PERIODS, BEFORE AND DURING THE 106-DAY PERIOD WHEN 2,4-D WAS ADDED TO THE DAILY RATION

10-day periods[1]	Live-weight	Milk production (4% fat corrected milk)	Grain consumed	Alfalfa hay fed	Timothy hay fed	Corn silage fed	Feed refused	
							Hay	Silage
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
1[2]	1180	29.1	9.8	5.0	12.0	14.0	—	.6
2	1189	24.9	10.2	5.0	12.0	14.0	—	.8
3	1219	27.2	8.7	5.0	12.0	14.0	—	.4
4	1218	26.7	9.5	5.0	12.0	14.0	—	—
5[3]	1224	26.7	9.6	5.0	12.0	14.0	.1	.1
6	1193	24.0	9.6	5.0	12.0	14.0	—	—
7	1186	24.6	8.5	5.0	12.0	14.0	—	—
8	1209	21.0	8.0	5.0	12.0	14.0	—	—
9	1213	19.0	6.9	5.0	12.0	14.0	.1	—
10	1214	16.6	5.0	5.0	12.0	17.6	—	—
11	1232	17.1	4.8	5.0	12.0	18.0	—	—
12	1231	15.2	4.2	5.0	12.0	18.0	—	—
13	1247	11.7	4.0	5.0	12.0	18.0	—	—
14	1260	11.2	5.8	5.0	12.0	18.0	—	—
15	1265	9.4	6.0	5.0	12.0	18.0	—	—

[1] The first 10-day period began 125 days after calving.

[2] Bred and settled with calf at beginning of this period.

[3] 5.5 gms. of 2,4-D added to daily ration at beginning of this 10-day period and for 106 days thereafter (July 30 to November 13, 1945).

As shown in table 2 the blood serum contained an average equivalent of 8.4 p.p.m. of 2,4-D an indication that this material or a derivative of it was taken into the blood stream. The blood serum of another Holstein cow not fed 2,4-D contained none of this material. Alcoholic extracts of the blood serum of the cow fed 2,4-D gave negative results, which indicates that this material was probably present as a water-soluble salt rather than as the acid.

Of sixteen samples of milk tested over the 106-day period, during which the cow consumed a total of 1.2 pounds of 2,4-D none showed a positive

TABLE 2. ACTIVITY OF BLOOD SERUM FROM A COW FED 5.5 GRAMS OF 2,4-D DAILY FOR THE PERIOD OF JULY 30 TO NOVEMBER 13, 1945 (106 DAYS) ALSO THAT OF SERUM FROM A COW NOT FED 2,4-D DURING THIS PERIOD. FIGURES RESPRESENT CONCENTRATION OF PURE SODIUM SALT OF 2,4-D REQUIRED TO STIMULATE INTERNODAL ELONGATION OF BEAN SEEDLINGS THE SAME AMOUNT AS IT WAS STIMULATED BY THE APPLICATION OF EXTRACTS OF THE SERUM

Date of sampling	Concentration (2,4-D Na equivalent), p.p.m.	
	Cow fed 5.5 gms. 2,4-D daily	Cow not fed 2,4-D
July 27	—	0
August 14	—	0
August 16	—	0
August 18	—	0
August 21	2.3	0
August 23	—	0
August 29	8.3	—
August 30	—	0
September 6	7.6	—
September 12	10.7	—
September 20	10.0	—
September 21	12.7	0
October 9	7.3	—
October 22	8.3	—

test.[5] Feeding 2,4-D produced no apparent effect on the flavor or odor of the milk. When this milk was fed to a young calf along with a small amount of grain, it made an average daily gain of 0.95 pounds which is considered normal for a calf of this age during the first 38 days of life. The calf maintained good health and vigor. Three samples of blood serum from this calf were negative when tested for the presence of 2,4-D.

When the cow that received the material in her feed over a 106-day period was slaughtered post-mortem examinations showed no pathological conditions that could be attributed to the 2,4-D. Water extracts of the kidney, liver, and fat tissue from this cow failed to give a positive test, thus indicating that the material did not accumulate in measurable amounts in these tissues.

Summary

Sheep and cows grazed pasturage treated with a liberal application of weed killer (2,4-dichlorophenoxyacetic acid and Carbowax mixture). There was no apparent reduction in its palatability. The 2,4-D consumed either on

[5] Dr. E. J. Kraus of the University of Chicago reported on January 26, 1946, that a human (adult male) had taken daily by mouth, 500 mgs. of purified 2,4-D either after the mid-day or evening meals during a period of 21 days without experiencing ill effects.

pasture grass eaten by sheep and cows or in the ration fed to a cow at the rate of 5.5 grams daily, produced no apparent harmful effects in the health and performance of the animals. Post-mortem examinations revealed no pathological conditions in cows grazing on pasture treated with 2,4-D nor was this material found to be present in the liver, kidney or fatty tissues of a cow fed 2,4-D.

By means of a biological method of assay, the presence of 2,4-D was demonstrated in the blood serum of a cow fed 5.5 grams of this material daily for 106 days. Results of these tests indicate that the 2,4-D probably occurred as a water-soluble salt.

The 2,4-D was not found to be secreted into the milk nor was it found in the blood serum of a calf fed milk from the cow that received it in her ration.

It is concluded from these data that the amount of 2,4-D that might be consumed by cows or sheep from pasturage sprayed with this material to kill weeds would not be injurious.

The present experiments are based on the use of purified 2,4-D together with Carbowax and, while they indicate that the acid is not toxic, the results are not applicable to proprietary formulations that might contain other ingredients.

Literature Cited

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AN EXAMINATION OF LIVESTOCK-JUDGING COURSES

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IN AN effort to devise ways and means of improving courses in livestock judging and selection at the University of California, relevant opinions were collected from livestock producers and educators in this country. Letters were written to animal and dairy husbandmen, to representatives of the packers, to deans of agricultural colleges, to geneticists, to presidents of universities, and to certain others, including the director of the office of Experiment Stations and a former Secretary of Agriculture of the United States. The survey was conducted, not by questionnaire, but rather by means of a letter that we hoped would elicit frank opinions.

Forty-five replies were received. Of this number, forty-two included information and constructive criticisms that could be classified. Twenty-nine reported some change or offered suggestions for improvement. A summary of the recommendations follow, with numbers indicating the replies in which each item was mentioned:

A combined study of the live animal and a comparable carcass	16
Credit for performance in evaluating animals	17
More emphasis on market animals, including market classes and grades	17
An attempt to coordinate knowledge of physiology and anatomy with judging techniques	16
Inclusion of a study of meat with the judging work	11
More use of classification judging and type conferences	10
The use of more group and feeder classes	9
Inclusion of research to develop a better basis for judgment	10
More visual instruction (such as the use of slides and photographs)	9
Use of an improved score card	9
Some de-emphasis of judging instruction	4

Many other suggestions were presented—for example, less handling of animals, less emphasis on purebreds and more emphasis on the type of stock found on average and good farms, more emphasis on young animals, instruction on market quotations, and more emphasis on the money value of animals used.

Many made comments like the following: excessive condition is wasteful; type should be emphasized; breeding animals used in class should be in farm condition, not fat; more stress should be placed on eyes in horses, udder development in swine, and sex characteristics in all animals; fancy carcass points (such as color of fat) often upset the on-foot placing; judging should include both type and performance; not enough is known about the cor-

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relation of animal form to function; the producer should recognize consumer preference and desires; students should be taught to recognize growth changes in breeding animals; show-ring ideals cause dairymen to follow false standards; herd improvement is more important than show-ring beauty; some time should be spent at the market and in the packing plants; students should recognize that feeding affects yield and quality of meat; judging teaches students to observe, to evaluate, and to decide; students should learn the ideal and see actual differences in animals studied; more classes of male animals should be provided; students should see animals at the beginning and end of the feeding period; an attempt should be made to show the correlation between outward appearances and the function of internal organs; representatives of all phases of the industry should get together and discuss their problems; some instructors teach with positiveness beyond justification.

According to the replies received, some changes and continued improvement in methods of instruction are desirable. The recommendations suggest greater emphasis on certain phases of the subject. Among the most significant are (a) continued research to secure a more definite basis for evaluating the animal or carcass, (b) an attempt to correlate animal form to anatomy and physiology, (c) the inclusion of performance records as a part of the instruction.

From the survey and from conversations with interested persons, the following general and specific recommendations seem important to the authors:

1. That tours of selected ranches, stockyards, and packing plants or wholesale establishments, livestock shows, and any other enterprise of benefit to animal husbandry students should be continued for the purpose of seeing and studying management problems, marketing methods, and slaughter procedures. Such tours should be reserved for advanced students and should be so arranged that they will not conflict with other classes.

2. That various grades of live animals and comparable carcasses and wholesale cuts be provided. This would require (a) animals of similar condition but differing widely in conformation, (b) animals of similar conformation but differing materially in condition. Since both classes would require comparable carcasses, slaughter equipment should be available, and some member of the instructional force should be qualified to handle the carcass part of the instruction.

3. That more time be given to the Danish system of judging, to breed classification, and to type studies. This will require the provision of enough animals to make up the various classes and groupings. In the Danish system the judge groups the animals in designated classifications of merit in a de-

scending order as contrasted with the more common system where the animals are placed individually—first, second, third, etc.

4. That more attention be given to analytical judging, or the comparison of the various parts of the body and the correlation of them to the conformation of the whole.

5. That students be taught to evaluate groups of animals (for example feeders, get of sire) as well as individuals.

6. The selection of breeding or foundation stock (especially the male animals) should receive more attention than at present.

7. That the facilities for instruction might be improved (a) by limiting to 45 the number of students in judging classes and (b) by providing illustrative material such as skeletons of various species of animals, charts of wholesale and retail cuts of meat and unsoundnesses in horses, wax models of lactating and dry udders, photographs and slides representing various breeds and hereditary defects.

8. That a score card, similar to that now used by the dairy groups, be developed for meat animals and for horses.

9. That the instructor in charge exercise his judgment in giving some experience to students not used to handling animals.

10. That dairy judging courses include, besides the selection of dairy cows by records and conformation, such topics as measurement of performance in breeding for high production; selection of the individual cow and of the herd sire through the use of pedigree, milk secretion, demonstrations, and herd-record analyses.

11. That an effort be made to standardize the names of livestock judging and selection courses in the animal-husbandry departments of the nation.

The authors are grateful for the response to the letters of inquiry sent out. Many ideas have been received and recorded. Some are included here in the hope that they will develop within the ranks of livestock husbandmen a discriminating and more constructive attitude toward the subject. Though we may not have progressed far, and though the selection of animals for reproduction and for slaughter is not yet an exact science, it is the opinion of the authors that the teaching of judging and selection has led to many improvements in American livestock; it has helped the producer to meet consumer demands. For continued success, additional basic data and even better methods of instruction are necessary.

NEWS AND NOTES

An Announcement of and Rules Concerning The Morrison Award

Professor F. B. Morrison of Cornell University, Ithaca, New York, and his wife, Elsie B. Morrison, have given the American Society of Animal Production "funds for a five-year-period for the establishment of an award each year to a member of the Society who has done outstanding recent research that has been of direct importance in livestock production." The award each year is to consist of one thousand dollars ($1,000) in cash and a gold medal or other suitable permanent form of recognition. The donors wish in this manner to express their appreciation of the help they have received from animal and dairy husbandry men in compiling the book "Feeds and Feeding." The awards are to be administered by the American Society of Animal Production under rules of its formulation. The Executive Committee of the Society unanimously accepted the funds and agreed to make the awards in accordance with the general and liberal wishes of the donors who will in no way influence decisions with respect to recipients.

The Executive Committee has formulated and adopted the following regulations and all awards shall be made in accordance with these stipulations.

1. To be eligible for The Morrison Award a nominee, who must be a member of the American Society of Animal Production, shall have made a meritorious scientific contribution or discovery in research in the field of animal husbandry.

2. The award is limited to living citizens of the United States and Canada actively engaged in research.

3. No officer or member of the Executive Committee of the American Society of Animal Production or member of committees concerned with the award shall be eligible for the award while holding such position.

4. The research must pertain to the following classes of animals: (a) beef cattle, (b) dairy cattle, (c) horses, (d) sheep, or (e) swine.

5. The research must relate to some phase of breeding, feeding, management, nutrition or physiology, or to the meats of the animals listed above in Item 4, and must have direct importance in their production.

6. The work on which the award is based may have extended over a considerable period of years but must have been completed or be in progress within the ten-year-period preceding the year in which the award is made. Some report of the research work must have been published within a five-year-period of the time at which the award is made.

7. Total recent accomplishment in a certain field as well as research relating to any particular problem may be the basis of the nomination for the award and such work shall be considered in determining recipients.

8. There are no restrictions with respect to race, sex or age.

9. No individual shall receive the award more than once.

10. The award may be to co-workers if deemed advisable by the Award Committee.

11. All nominations for the award for each year shall be made in writing to the Secretary of the American Society of Animal Production. Nominations must be received by the Secretary *before* June 15 of the year in which such nomination is made.

12. Any member of the Society in good standing, except officers, members of the Executive Committee, and members of the Award Committee, may make nominations. No member may make more than one nomination in any one year.

13. The Award Committee shall consist of five members. The Vice President of the Society shall be chairman of this committee. The President of the American Society of Animal Production shall appoint the other members. In 1946 two members shall be appointed for one year and two members for two years. Thereafter two members shall be appointed each year for a two-year-term. Any vacancies shall be filled by new appointees named by the President.

14. All nominations must be accompanied by a brief biography of the nominee and a list, together with copies, of publications concerning the research, and a statement of the importance to the livestock industry of the work upon which the nomination is based.

15. After nomination has been made, solicitation on behalf of any nominee by individuals, groups, or institutions, will not be tolerated, and such solicitation will automatically make the nominee ineligible for the award.

16. All nominations, together with supporting material, received by the Secretary will be transmitted to the Chairman of the Award Committee immediately after closing date for nominations, and the Committee shall report its selection to the Secretary not later than November first. These dates are used in reference to each year in which an award is made.

17. The decision of the Award Committee in the selection of a recipient shall be final. If the Committee decides none of the nominees is deserving of the award, no award will be made that year.

18. The presentation of the award will be made under appropriate circumstances at the time of the annual meeting of the American Society of Animal Production.

19. If a recipient is selected the first award will be made in 1946.

20. The Executive Committee may make necessary changes in these regulations for awards in subsequent years.

Availability of Copies of Proceedings

Since the publication of the Index of the Proceedings in the February, 1946 issue of the JOURNAL OF ANIMAL SCIENCE, there may be some demand for copies. The following is a complete list of those available, together with the numbers of copies, on April 1, 1946:

Year	*Number*	*Year*	*Number*
1915–1916	71	1932	41
1920	18	1933	59
1922	380	1934	62
1923	254	1935	62
1925–1926	73	1936	22
1927	71	1938	19
1929	53	1939	37
1930	39	1940	97
1931	86		

No copies are available for the years not listed. Copies of those available may be obtained from the Secretary of the Society, Dr. W. G. Kammlade, 110 Stock Pavilion, University of Illinois, Urbana, Illinois. The price is $1.25 per volume to members and $2.50 to non-members. Prices for sales outside the United States may be obtained from the Secretary.

Availability of Reprints of Index to Proceedings of American Society of Animal Production

Reprints have been prepared of the "Index to Proceedings of American Society of Animal Production" which appeared in the February, 1946 number of the JOURNAL OF ANIMAL SCIENCE. Members, libraries and others desiring copies of this index to file with their Proceedings may obtain them from the Secretary of the Society, for fifty cents per copy.

Availability of Back Numbers of the Journal of Animal Science

There are no complete sets available for sale to individuals. Only 53 complete sets are left of those put aside for sale to libraries. In addition to those sets, the following were available on April 1, 1946:

		Copy number			
Volume	*Year*	*1*	*2*	*3*	*4*
1	1942	32	106	109	140
2	1943	151	126	105	118
3	1944	71	9	34	40
4	1945	none	none	none	none

Copies may be obtained from the Secretary of the Society. Prices within the United States are $1.00 per single copy and $3.50 per volume. Prices for sales outside the United States may may be obtained from the Secretary.

Other News Items

The next annual meeting of the American Society of Animal Production will be held at the Hotel Sherman in Chicago on November 29 and 30, 1946. Abstracts of papers to be presented at the meeting will be published in the November issue of the JOURNAL OF ANIMAL SCIENCE. Titles and abtsracts of papers must be in the hands of the Secretary, Dr. W. G. Kammlade, by September 10, preceding the meeting. Abstracts must not exceed 250 words in length. See Item 5 of "Information for Contributors" for instructions on the preparation and typing of abstracts.

The Western Section of the American Society of Animal Production will renew the holding of an annual meeting this summer. Officers of the Section are: President, J. H. Knox of New Mexico; Vice-President, F. S. Hultz of Wyoming; Secretary, E. B. Stanley of Arizona. The meeting will be held at the Hotel Utah in Salt Lake City on June 24 and 25, 1946. Room accommodations have been set aside for the group, but members will make their reservations directly with the hotel. Titles of papers may be sent to the Secretary, E. B. Stanley, at Tucson, Arizona, any time up to June 10.

E. J. Perry of Rutgers University is the editor of a book entitled "The Artificial Insemination of Farm Animals" which was published in 1945 by the Rutgers University Press, New Brunswick, New Jersey. This book deals with the application of artificial insemination in all classes of farm livestock and poultry. It is intended for the use of farmers and field workers who are using artificial insemination, and for animal husbandry and veterinary workers. The following participated in the preparation of the book: John W. Bartlett, George E. Taylor, Joseph Edwards, Clair E. Terrill, Victor Berliner and Fred P. Jeffrey.

C. W. Hodgson, formerly of the University of Nevada, has joined the animal husbandry staff at the University of Idaho. He replaces W. M. Beeson, who recently accepted a position at Purdue University.

Hubert Heitman has recently joined the staff of the Animal Husbandry Department, University of California, at Davis. He took his undergraduate work at Davis, obtained the degree of Doctor of Philosophy at the University of Missouri, and has been serving as a captain in the Sanitary Corps of the United States Army.

A. E. Darlow, head of the animal husbandry department, Oklahoma A & M College, returned on January 29 from 8 months service in the United States Army Educational Center at Shrivenham, England, but two days later started back to Scotland where he acted as judge at the Perth Show. He is back again and serving as head of the department at Stillwater.

D. W. Williams, who has been overseas with A.M.G. in the Italian and Austrian theaters, returned home in December and is now vice-president of the Texas A & M College, where he formerly served as head of the Animal husbandry department.

Paul E. Howe, formerly of the U. S. Bureau of Animal Industry, who has been on active duty with the War Department in the field of nutrition, serving in Europe, India and China, is now in Japan on a similar assignment.

H. G. Sellards, who has been on active duty with the U. S. Army for several years, serving most recently on the staff of the Army University Educational Center in England, returned to his duties as extension animal husbandman at the University of Kentucky on March 1.

DeWitt C. Wing is now director of information for the American Aberdeen Angus Breeders' Association, with headquarters in Chicago.

D. H. LaVoi is now back with the National Live Stock and Meat Board as director of the Department of public relations, after a period of retirement due to illness.

L. J. Cole of the University of Wisconsin suffered a stroke in February while at Austin, Texas, preparatory to delivering a lecture before a scientific group at the University of Texas.

Howard Davison, for several years one of the extension animal husbandmen at Ohio State University, has resigned to accept the position of public relations director of the Central Cooperative Livestock Marketing Association at South St. Paul, Minnesota, effective April 15.

L. F. Taylor has been appointed extension animal husbandman at Kansas State College in which capacity he will specialize on 4-H Club projects.

W. E. Carroll has returned from Europe where he headed the animal husbandry staff at the United States Army Educational Center, Biarritz, France, and has taken up his duties as head of the animal husbandry department at the University of Illinois.

T. O. Larsen, extension animal husbandman at the South Dakota State College, has resigned to accept private employment.

Rollie J. Pemberton, formerly field secretary of the Iowa Swine Producers' Association, became secretary of the American Hampshire Registry Association, effective February 15, succeeding E. M. Harsch, deceased. R. Alan Williams, recently returned from military service and former county agent in Keokuk County, Iowa, has succeeded Mr. Pemberton.

William P. Tyrell, a graduate of Purdue University, has been appointed assistant extension animal husbandman at the University of Tennessee.

W. H. Peters of the University of Minnesota is confined to the hospital, following serious major operations.

Meade T. Foster, formerly with the U. S. Department of Agriculture, and for the past year agricultural foreign service officer with the Department of State in Brazil and Argentina, has been made agricultural attache in the same service at Ottawa, Canada.

F. F. McKenzie of the Oregon State College has been awarded the honorary degree of doctor of veterinary science by the University of Chile, following his 2 months service in that country on an artificial insemination program.

Francis J. Cronin is now chief of the Wool Division, Livestock Branch, Production and Marketing Administration, United States Department of Agriculture, succeeding Alexander Johnston, who resigned to return to the University of Wyoming.

K. F. Warner, senior extension specialist, United States Department of Agriculture, has been awarded a certificate of appreciation by the Quartermaster Corps, United States Army, for contributions to the war food effort.

Edwin C. Weatherby, a graduate of Cornell University and for the past several years manager of the artificial breeding association at Sussex, New Jersey, is manager of a similar enterprise being set up in Maryland.